# NATURAL RESOURCES OF THE WORLD

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## Summary

Natural resources are materials, energy, and their attributes that are derived from the Earth and are useful to the maintenance and improvement of the quality of human life. Renewable resources are those that are continually available, like solar energy and wind power, or that can be replaced within the lifespan of humans such as wood, plants, and animals. Nonrenewable resources are formed over geologic time and are not readily replaceable; examples include petroleum products, copper ore, coal, and aluminum. Our natural resources are drawn from land and minerals, air and water, and include solar and biological resources, as well as their attributes (for example, some societies value an aesthetically pleasing landscape view as a natural resource). We exploit them not only to satisfy our needs for the raw materials of major industries, but also for their spiritual values. These resources are not merely consequential components of the Earth, but are the products of the interactions of plants, animals, climate, soils, and water that are linked together by the flow of matter and energy. The harmonious links between soils, plants, animals, solar energy, and water in a functioning Earth ensures the availability of natural resources such as clean water, fertile soil, and clean air to sustain human existence. The future of these resources is dependent on maintaining these delicate balances of energy transfer within our planet.

Humans depend on the flow of energy within our environment: the whole history of human civilization recounts the tale of the quest for energy for sustenance, reproduction, and comfort. We continually search for efficient means to extract energy from natural resources in order to allow us to do more than merely survive and reproduce; we seek the enhancement of our quality of life. The world's increasing population and our ceaseless desire to improve our quality of life put pressure on the finite quantity of natural resources. This has prompted humans to harness alternate energy sources such as solar and wind energy. We are easing our dependency on traditional resources and striving to develop technologies and adapt management strategies to include non-traditional resources.

## 1. Introduction

Natural resources are materials, energy, and their attributes that are derived from the Earth and are useful or of value to the maintenance and improvement of the quality of human life. "World resources" is a term often used synonymously with natural resources. Natural resources are often categorized as renewable or nonrenewable. The former are those that are continually available (solar energy, wind power) or can be replaced within the lifespan of humans (wood, plants and animals). Nonrenewable resources, formed over geologic time and not readily replaceable, include petroleum products, copper ore, coal, and aluminum. Traditionally, natural resources are the extracted naturally occurring materials, particularly energy and raw materials that are valuable to major industries or a security of the country. However, different societies have different perceptions and valuations of resources due to cultural, economic, and technological values. Some societies value natural attributes such as landscape as an important natural resource, or look to the spiritual values of a unique rock formation or the oldest tree in a forest. It is no wonder that more than 700 cultural and natural sites around the world are protected by the World Heritage Committee. This ensures that future generations can inherit the treasures of the past while enjoying the aesthetics of natural sites. The cultures of many indigenous societies of the Americas, Africa, and Asia are considered important resources to many outdoor enthusiasts, and are not to be extracted but to be preserved to enhance the quality of human life. The differential valuation of resources in various societies is recognized in the Rio Declaration on Environment and Development, particularly Principle 2, which states that “states have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies.”

*Agenda 21* also refers to the “life supporting” capacities of our planet as the interactive processes related to “the use of land, water, air, energy, and other resources.” In a sense, “life supporting capacities” of the Earth are our natural resources because the sustainable development of these resources must be centered on human beings, who are “entitled to a healthy and productive life in harmony with nature.” Our Earth supports human life.

Natural resources are the products, and not merely consequential components, of the Earth. The Earth, our home, is not just a conglomeration of matter, but a functioning system composed of plants, animals, climate, soils, and water linked together by the flow of matter and energy. For example, soils act as a natural filter to ensure good quality water for human and animal consumption. The soil provides plants with a growth medium containing water and essential nutrients. In addition to water and nutrients, plants use solar radiation during photosynthesis to convert solar energy to forms usable by humans and animals, and in the process prevent the excessive build up of carbon dioxide in the atmosphere. Plants also generate the oxygen that enables animals and humans to benefit from chemical energy through the oxidation of foods and food products. The harmonious links between soils, plants, animals, solar energy, and water in a functioning Earth ensures the availability of natural resources such as clean water, fertile soil, and clean air to sustain human existence on our planet. The future of these resources is dependent on maintaining these delicate balances of energy transfer.

### 1.1. A brief history of resource use

The history of human civilization is the history of natural resource utilization, particularly energy acquisition and use. For the past two million years, hominids have been extracting or using natural resources to generate energy for their metabolic needs. Humans need about 2,500 kilocalories every day to survive and reproduce. Early gatherers and hunters relied mostly on plants, animals, air, and water for their survival or energy needs. They needed energy not just for themselves, but also for the young and elderly who were unable to take part in hunting and gathering activities. To generate surplus energy, they learned to use rocks (such as flint) as weapons to hunt more efficiently. They learned to practice agriculture by raising domesticated animals, cultivating plants, and extracting iron ores to improve their means of energy acquisition. The improved means of energy acquisition is indistinguishable from our present-day concept of improved quality of life. Human life was no longer restricted to the acquisition of energy for maintenance and reproduction; they used energy to express their feelings and emotions through art, such as early cave paintings. Excess energy enables human beings to realize their potential, build self-confidence, and lead lives of dignity and fulfillment, or simply improve the quality of their life. The insatiable needs of humans to improve their quality of life continued with the extraction and usage of other metals, including copper and steel, to capture energy more efficiently. The extraction of Earth's natural resources continued with the Industrial Revolution after the seventeenth century when humans harnessed wind power through windmills, or generated power from steam engines. From then on, the extraction of natural resources grew exponentially with the growth of human populations. First, humans developed technology based on iron and steel, followed by chemical technology, then the plastic, nuclear, electronics, and computers and now, biotechnology. These technologies, no matter how advanced, require some form of natural resources. For example, computer and electronic technologies need silicon, biotechnology needs genes extracted from plants and animals, and precision agriculture requires fertilizers. These continuing demands for natural resources put pressure on their finite quantity; but they also force us to explore non-traditional sources of energy. It is not only the quantity of remaining resources that is threatened, but also the integrity of the system. It has been shown through the ages that over-utilization of finite resources could lead to the demise of some human civilizations, for example from the loss of arable land resources. If humans are to continue to survive on the Earth, we should be aware of its system integrity and be conscious of the delicate interactions between that and our resource extraction activities. The quest for better sources and more efficient acquisition of energy are the ultimate challenges of mankind.

### 1.2. Renewable resources

Renewable resources are the products of the natural processes resulting from the harmonious interactions of the physical and biological components of the Earth's systems. Like other resources, they are utilized and harvested to meet the basic needs of humans. Renewable resources regenerate naturally as long as the well-balanced flow of matter and energy within the system is not altered by natural catastrophe or human activity. Harmonious interactions or a well-balanced flow of matter and energy imply a properly functioning ecosystem where plants and animals (including microorganisms) have a sufficient supply of water, nutrients, and energy for survival and reproduction. Renewable resources may be biological in nature (such as animals or plants) or non-biological (such as the fertility of soils and availability of water to support forestry and agriculture). As long as the rate at which renewable resources are used is not greater than the rate at which they grow or accumulate, renewable resources can supply the needs of humans. When the rate of use exceeds the rate of renewal, resources will be depleted and will not be available for future generations.

From a purely economic perspective, renewable resources are those in which natural replenishment augments the flow at a non-negligible rate. Management of renewable resources involves maintaining the flow of the product over long periods of time. It is possible for these resources to be replenished in perpetuity, provided proper stewardship is maintained and that the resources are given sufficient time for recovery following extraction or use. It is also possible for some renewable resources to be stored, which allows for better management of supply or allocation over time. For example some foods, such as grains, may be stored for months or years in order to ensure ample access to the resource during times of short supply. At present, the best means for storing solar energy is through photosynthetic conversion to biomass, the bulk of which is done by forests and the marine ecosystem. However, it should be noted that more than a quarter of the net primary productivity on the Earth ($60.1 \times 10^{15}$ g year$^{-1}$ of the total $224.5 \times 10^{15}$ g year$^{-1}$) is controlled by human activities. As noted by Simmons (1991), natural resource depletion is rarely entered in national income accounting. It is possible for a country to exhaust its minerals, erode its soils, burn and log its forests, grossly contaminate its air and water resources, and fish out its seas, and the way in which national income is measured would not reflect those changes.

Most of these renewable resources supply directly the food and shelter needs of humans. Statistics showed that the world production of fish, shellfish, and other aquatic species is 125 million tons, while global production of roundwood and pulp and paper products were 3,275 million cubic meters and 480 million tons, respectively.

### 1.3. Nonrenewable resources

Nonrenewable resources are those that are present in finite quantities and cannot be regenerated within the lifespan of humans after they are harvested or used. These include fossil fuels, minerals, and ores. These resources generally are not common and are found in specific places where conditions were suitable for their establishment. They are considered nonrenewable because the rate at which they are regenerated is extremely slow on the timescale of human perspective. For example, it takes millions of years for plant material to be converted into fossil fuels such as coal. Copper, diamonds, uranium, and other minerals are other nonrenewable resources. Some groundwater systems (aquifers) are nonrenewable. Namibia and Botswana, being the driest countries in southwestern Africa, have many nonrenewable aquifers that are being depleted faster than they can be replenished naturally.

### 1.4. Other (renewable energy) resources

Some other Earth resources can be classified as perpetually available. They are always available in relatively constant or predictable supply regardless of how we utilize them. These resources are primarily energy sources such as solar, wind, wave, and geothermal power. Utilization of these resources is slowly replacing the traditional sources of energy (e.g. fossil fuel and wood) as the primary source of energy. In 1999, an estimate of energy supplied by non-conventional sources such as solar, wind, tidal, and geothermal power amounted to over 200 billion kWh. Potentially renewable resources such as groundwater, soil, and plants require management or stewardship; if the rate of exploitation exceeds that of natural renewal, then the resource will be depleted.

## 2. Renewable Resources

### 2.1. Land resources of the world

#### 2.1.1. Natural zonation

Land resources of the world have natural zonation with respect to the interaction of the physical, chemical, and biological components. The zonation is governed by the global flow of energy and its influence on natural processes such as climate, soil development, and biome establishment. The fundamental geographical zone has been referred to as a "landscape belt," a "geozone," an "ecoclimatic region," a "geographic zone," an "ecosystem," and more recently, as an "ecozone." Within each zone, soils developed from similar parent geological material and slope position will develop similar trends in vegetation development under similar climatic conditions. Each zone has distinctive ecological responses to climate as expressed by plant and animal associations, soil types, available water, and seasonal temperatures. Zonation is often used for an evaluation of the biophysical limitations and potentials of land resources for agriculture and forestry, and hence these areas are sometimes called "agro-ecological zones."

Natural zones are large geographic areas (millions of square kilometers) with characteristic climate, soil units, plant and animal associations, and landforms. Divisions of land resources into zones are by no means simple because of several factors including: the wide range of small-scale variations in environmental conditions; many landscape features that have developed over long periods of time; and natural disturbance, such as fire, that creates non-climax vegetation at various stages of succession. Despite these limitations, natural zonation of land resources is possible and useful, but it is important to be aware, first, that zonal boundaries are drawn arbitrarily, and second, that variations in each zone remain naturally large. Authors have proposed several natural zonation systems, all of which are influenced heavily by climatic classification, such as the Koppen System and Paffen System.

*Table 1.* Aerial distribution of ecozones of the world

| *Ecozone* | *Surface area ($10^6$ km$^2$)* | *Proportion of land mass (%)* | *Growing season (months)* | *Mean annual temperature (°C)* | *Mean annual precipitation (mm)* |
|---|---|---|---|---|---|
| Polar/subpolar | 22.1 | 14.8 | <3 | <0 | <200 |
| Boreal | 19.5 | 13.0 | 4–6 | <5 | 250–500 |
| Humid mid-latitudes | 14.5 | 9.7 | 7–11 | 6–12 | 500–1 000 |
| Arid mid-latitudes | 16.4 | 11.0 | <5.5 | Variable across the ecozone | 0–500 |
| Tropical/subtropical arid lands | 31.2 | 20.9 | 7 | 5–18 | 100–250 |
| Mediterranean-type subtropics | 2.7 | 1.8 | 5–9 | 5–18 | 300–900 |
| Seasonal tropics | 24.4 | 16.3 | 5–9 | >18 | 1 000–1 500 |
| Humid subtropics | 6.1 | 4.1 | 10–12 | 5–18 | 500–2 000 |
| Humid tropics | 12.5 | 8.3 | 10–12 | >18 | 2 000–3 000 |

Table 1. Aerial Distribution of Ecozones of the World

The literature divides the terrestrial land resources of the world into nine ecozones with further division into sub-regions in some cases. These ecozones are (1) polar/subpolar, (2) boreal, (3) humid mid-latitudes, (4) arid mid-latitudes, (5) tropical/subtropical arid lands, (6) Mediterranean-type subtropics, and (7) seasonal tropics, (8) humid subtropics, and (9) humid tropics. The worldwide distribution of the different ecozones is given in Table 1 and graphically in Plate 16.3–1.

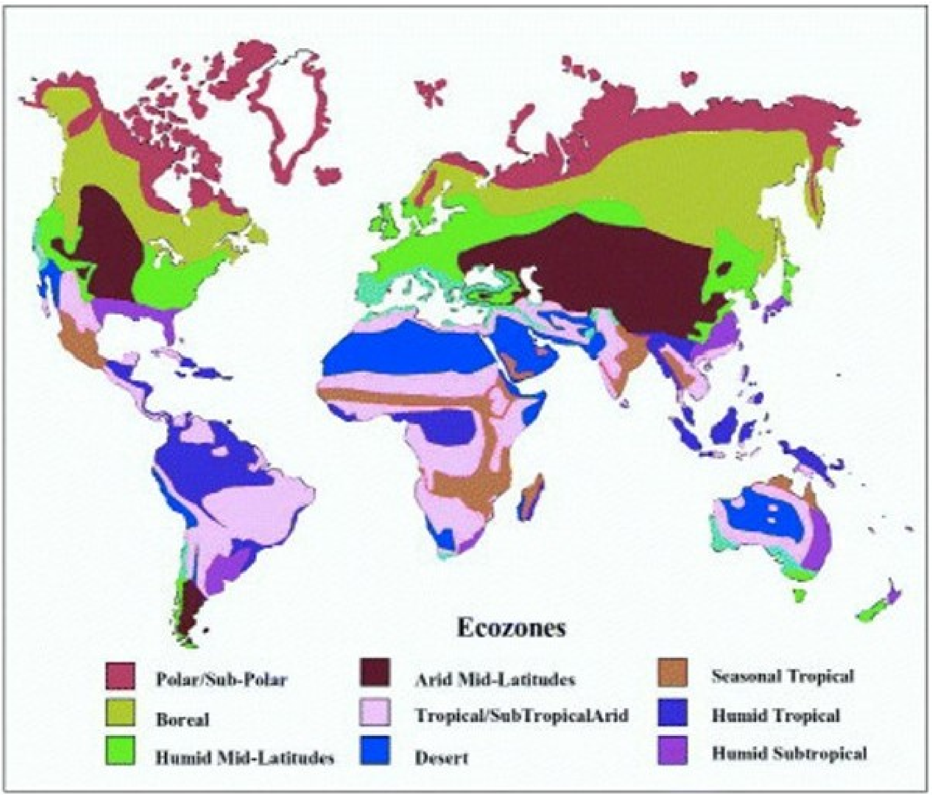


Plate 1. Distribution of Ecozones of the World ( after Schultz, 1995; Freedman, 2001)

**POLAR/SUBPOLAR ECOZONE**

The polar/subpolar zone is located along the coastlines of the Arctic and the Antarctic and covers 15 percent of the terrestrial land mass (Table 1). It is divided into the sub-regions of (1) tundra and frost debris zone, and (2) ice desert. The climate and biome within this zone are referred to as tundra. Tundra climate is characterized as cold desert with annual precipitation of less than 200 mm, mean annual air temperature below 0 °C, and the mean temperature of the warmest month between 6 and 10 °C. The incoming radiation in one growing season ranges from 50 to 150 × $10^8$ kJ $ha^{-1}$. Soils with permafrost (gelic soils), or a soil horizon where temperature remains below freezing most of the year, are common in this zone (Table 2). Vegetation is dominated by lichens (e.g. *Rhizocarpon* and *Cladonia*), and mosses (e.g. *Polytrichum* and *Dicranum*). Other plant species are dwarf shrubs (e.g. *Vaccinium*, *Dryas*, *Betula*, *Arctostaphylos*), sedges *Carex*, and grasses (e.g. *Hierochloe* and *Poa*), willows *Salix* and horsetails *Equisetum*. Animals living on the tundra are mostly homoiotherms, and consist of musk ox *Ovibos moschatus*, reindeer and caribou *Rangifer tarandus*, arctic hares *Lepus arcticus*, wolves *Canus lupus*, and foxes *Vulpes vulpes*. Examples of bird species include the snowy owl

*Nyctea scandiaca*, ptarmigans *Lagopus*, and sandpipers (Calidridae), as well as water fowl (ducks, geese and swans of the family Anatidae). Agriculture is limited because of the short growing season (less than three months), low levels of solar radiation and, in many cases, waterlogged conditions. Land use is restricted to herd management, such as those of reindeer. The infrastructures for human settlements and industrial explorations (e.g. oil and minerals) in the polar/subpolar ecozone are erected on stilts to tolerate the periodic movement of the foundation due to alternating freeze and thaw processes, as well as to prevent heat transfer between the structures and the underlying permafrost. One of the concerns related to human utilization of the land resources in this ecozone is the thawing of the active layer associated with the removal of tundra vegetation. Other places on Earth experiencing similar habitat conditions as well as a similar plant and animal biome are the high reaches of the Andes and Himalayan mountains.

| **Soil Group / hectarage ($10^6$ ha) / associated soil groups** | **Brief Description** | **Distribution** |
|---|---|---|
| **Acrisols** / 10000<br><br>Nitisols, Ferralsols, Plinthosols, Lixisols, Arenosols, Regosols and Cambisols. | Soils with subsurface accumulation of low activity clays and low base saturation. | Most extensive on acid rocks in Southeast Asia, Southeast USA, the southern fringes of the Amazon basin and in both east and west Africa |
| **Albeluvisols** / 320<br><br>Luvisols, Gleysols and Podzols | Acid soils with a bleached horizon penetrating into a clay-rich subsurface horizon. | Albeluvisols stretch eastward from the Baltic Sea across Russia into central Siberia. Scattered smaller areas occur in western Europe and the United States. |
| **Alisols** / 100<br><br>Acrisols,<br>Lixisols and Ferralsols | Soils with subsurface accumulation of high activity clays, rich in exchangeable aluminum. | Alisols are typically found in the southeastern United Staes, Latin America, Indonesia and China. |
| **Andosols** / 110<br><br>Cambisols, Luvisols and Vertisols. | Soils devloped in volcanic deposits. | They occur around the Pacific rim, including North and Central America, the Andean region, Indonesia, Philippines, Japan and New Zealand as well as along the African Rift Valley. |
| **Arenosols** / 900<br><br>Leptosols, Regosols, Calcisols, Solonchaks and Podzols. | Sandy soils featuring very weak or no soil development. | These soils occur on deep aeolian, marine, lacustrine and alluvial sands, mainly in the Kalahari and Sahel regions of Africa, and in Western Australia and South America. |
| **Calcisols** / 800<br><br>Regosols, Cambisols, Gypsisols and Solonchaks | Soils with accumulation of secondary calcium carbonates. | Calcisols occur in western USA, Saharan Africa, Southwest Africa, the Near East and Central Asia. |

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| **Cambisols** / 1500<br><br>Gleysols, Leptosols, Fluvisols, Acrisols and Ferralsols | Weakly to moderately developed soils. | Cambisols occur worldwide, with dominance in the temperate regions. They are common on Pleistocene and other parent materials |
| **Chernozems** / 230<br><br>Luvisols, Phaeozems and Kastanozems | Soils with thick, blackish topsoil, rich in organic matter and a calcareous subsoil. | Chernozems are found in cooler mid-latitude steppes and prairies of South America, Eurasia and North America. |
| **Cryosols** / 1770<br><br>Podzols, Histosols and Gleysols. | Soils with permafrost within 1 m depth. | Arctic and subarctic regions of Canada, Alaska, Russia, China and in Antarctica. They also occur at high elevation in mountainous areas. |
| **Durisols** / not available<br><br>Gypsisols, Calcisols, Arenosols, Cambisols and Vertisols. | Soils with accumulation of secondary gypsum. | These soils are extensive in Australia, South Africa and America. As they have not been mapped separately, an estimate of their extent is not available. |
| **Ferralsols** / 750<br><br>Acrisols, Nitisols, Plinthosols and Cambisols | Deep, strongly weathered soils with a chemically poor, but physically stable subsoil. | Ferralsols are restricted to tropical regions, mainly South and Central America and Central Africa, with scattered areas elsewhere. |
| **Fluvisols** / 350<br><br>Histosols and Gleysols. | Young soils in alluvial deposits. | Worldwide occurrence on river floodplains, deltaic areas, and coastal marine lowlands. |
| **Gleysols** / 720<br><br>Cryosols, Podzols, Hystosols, Fluvisols, Calcisols, Gypsisols, Acrisols, Lixisols, Alisols and Nitisols. | Soils with permanent or temporary wetness near the surface. | Gleysols occur in sub-arctic areas of northern Russia, Siberia, Canada and Alaska. They are also present in humid temperate and low-land inter-tropical regions. |
| **Gypsisols** / 90<br><br>Calcisols | Soils with accumulation of secondary gypsum. | Worldwide distribution similar to that of Calcisols. Excellent examples are found in Bahrain, Oman and Tunisia. |
| **Histosols** / 315<br><br>Podzols, Gleysols and Fluvisols | Soils formed from organic materials. | Histosols occur in the northern parts of America, Europe and Asia. They are also found on coastal low-lands of the subtropics and tropics. |
| **Kastanozems** / 465<br><br>Chernozems, Calcisols, Gypsisols, Solonetz and Solonchaks. | Soils with a thick, dark brown topsoil, rich in organic matter and a calcareous or gypsum-rich subsoil. | Kastanozems occur on the southern steppes of Ukraine, southern Russia, Mongolia and the Great Plains of the USA. |
| **Leptosols** / 1655 | Very shallow soils over hard rock or in | Leptosols are most common in mountainous areas and deserts. |

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| Regosols, Cambisols, Arenosols, Calcisols, Gypsisols | unconsolidated very gravelly material. | |
| **Lixisols** / 435 | Soils with subsurface accumulation of low activity clays and high base saturation. | Lixisols are found mainly in Brazil, West Africa, East Africa and India. |
| **Luvisols** / 650<br><br>Cambisols and Gleysols | Soils with subsurface accumulation of high activity clays. | Central and western Europe, around the Mediterranean Sea and North America. Smaller areas occur in Australia and southeastern parts of the Republic of South Africa. |
| **Nitisols** / 200 | Deep, dark red, brown or yellow clayey soils having a pronounced shiny, nut-shaped structure. | Eastern Africa, particularly in Kenya, Ethiopia and Tanzania. Smaller areas occur in India, the Philippines, Java, Central America and Brazil. |
| **Phaeozems** / 190 | Soils with a thick, dark topsoil rich in organic matter and evidence of removal of carbonates. | Phaeozems are distributed mainly in the more humid steppes of Russia, the prairies of USA and Canada, the pampas of Argentina and Uruguay, China and southeastern parts of Europe. |
| **Planosols** / 130<br><br>Acrisols, Luvisols and Vertisols | Soils with bleached, temporarily water-saturated topsoil on a slowly permeable subsoil. | Planosols are extensive in Brazil, northern Argentina, South Africa and eastern Australia. Smaller areas occur in southeast Asia from Bangladesh to Vietnam and in the eastern United States. |
| **Plinthosols** / 60<br><br>Ferralsols, Acrisols and Alisols. | Wet soils with an irreversibly hardening mixture of iron, clay and quartz in the subsoil. | West Africa, parts of South America, India and Western Australia. Ironstone, or hardened plinthite is more widely spread and often associated with old, high level pene-plains of the southern continents. |
| **Podzols** / 485<br><br>Anthrosols, Cryosols, Cambisols, Gleysols and Histosols, and in the humid tropics, mainly Acrisols and Arenosols. | Acid soils with a blackish/brownish/reddish subsoil with alluvial iron-aluminum-organic compounds. | Podzols occur mainly in northern Russia, Siberia and northern Canada. Scattered, smaller areas occur on coarse parent materials associated with heathland. |
| **Regosols** / 260<br><br>Leptosols and Arenosols | Soils with very limited soil development. | Regosols occur mainly in arid areas, the dry tropics and in mountainous regions. |
| **Solonchaks** / 260-340<br><br>Gleysols and Solonetz | Strongly saline soils. | Solonchaks occur where evaporation exceeds rainfall and there is a seasonal or permanent water table |

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| | | close to the soil surface, or in coastal areas influenced by saline intrusions. Saharan Africa, East Africa, Namibia, Central Asia, Australia and South America. |
| **Solonetz** / 135<br><br>Solonchaks and Gleysols. | Soils with subsurface clay accumulation, rich in sodium. | Scattered areas throughout the world where there is predominance of sodium over calcium salts in soils. |
| **Umbrisols** / 100 | Acid soils with a thick, dark topsoil rich in organic matter. | Umbrisols occupy Western Europe, the northwest seaboard of USA and Canada, the mountain ranges of the Himalayas and the mountain ranges of South America. |
| **Vertisols** / 335<br><br>Luvisols, Cambisols, Gypsisols and Solonchaks. | Dark-coloured cracking and swelling clays. | Vertisols occur in central Sudan, East Africa, the Deccan Plateau of India, Texas, South America and Australia. |

Source: FAO-AGL. 2000. Land and Plant Nutrition Management Service. World Reference base for soil resources. Available on-line at http://www.fao.org/ag/agl/agll/wrb/mapindex.htm#top. Date accessed: January 28, 2002.

Table 2. Brief description and distribution of major soil groups of the world (after FAO-AGL, 2000).

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