

## **ARID ZONE FORESTRY WITH SPECIAL REFERENCE TO INDIAN HOT ARID ZONE**

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## Summary

Arid environments are extremely diverse in terms of their land forms, soils, fauna, flora, water balance, and human activities. The binding element of all arid environments is aridity. Of the total land area of the world, arid zones account for 18.8%. Water is a scarce commodity in arid zones, and much of the rainfall is lost by

evapotranspiration. In arid zones, vegetation is typically sparse, and woody species richness is low. Arid zones are located in almost all continents. Africa accounts for 46.1% of the total area of arid zones, followed by Asia with 35.5%. There is no dearth of problems in arid zones, but increasing desertification and land degradation are problems of a worldwide dimension. At the world scale, the GLASSOD database indicates that in arid zones, the major cause of land degradation is soil erosion, and that more than 60% of soil erosion is caused by wind. Besides wind and water erosion, overgrazing, agricultural activities, overexploitation of vegetation for domestic use, and faulty land use are other factors responsible for ever increasing soil degradation.

The hot arid zone of India is situated between 24° and 29° N latitude and 70° and 76°E longitude, and covers an area of 31.70 million hectares. The arid areas of western Rajasthan, Gujarat, Punjab, and Haryana, together constitute the great Indian desert, better known as the Thar Desert, which accounts for 89.6% of the total hot arid zone of India. Thus the Thar constitutes the principal hot arid zone of India. It extends for 640 km from northwest to southeast with an average width of 300 km. Slightly more than 10% of the arid region lies in Andhra Pradesh, Karnataka, and Maharashtra states, and is referred to as the peninsular hot arid zone. In general, climatic and edaphic conditions of the Indian hot arid zones are inhospitable; however, this is the most populated arid zone of the world, with a density of 101 persons/ km<sup>2</sup> against the world average for arid zones of 6–8 persons/km<sup>2</sup>. The Indian hot arid zone is also the most vegetated arid zone. Farmers grow arable crops in association of tree species. Because most of the trees are drought resistant, they are still able to provide fuel, fodder, fruits and other products, when other crops fail due to the frequent drought. Thus, trees are an important component of life support in the hot Indian arid zone.

The vegetation of the hot Indian arid zone is broadly classified as tropical thorn forests. In general, vegetation is very sparse and hostile environmental conditions do not support the much required natural regeneration and subsequent growth of plants. The vegetation has been described and classified by various workers on a floristic and physiognomic, quantitative basis mainly involving dominance indices. A total of 682 species in 352 genera are found in the zone, of which only 9.4% are endemic; 49 are tree species. This article attempts to explain the vegetation of the Indian hot arid zone with special reference to tree species, and is organized systematically to provide a clear idea account in terms of location, physiography, climate, population, life support systems, vegetation, relationship between humankind and trees, etc.

## **1. Introduction**

Of the total land area in the world, arid zones cover 18.8%. The hyper-arid zones account for 22.3% of the total arid zones. These arid zones are diverse in terms of climate, soils, vegetation, animals, and lifestyles and activities of people. Little but variability in rainfall and the presence of distinctive periods of drought are the characteristics of the arid tropics. Precisely, the hot arid areas are those places that have little and highly variable rainfall, extreme variation in temperature (daily and annual) and high potential evapotranspiration. In general, hot arid climates have excessive heat and strong prevailing winds, unhampered by obstacles on the ground, and as a result Aeolian erosion is common with frequent seasonal occurrence of dust storms.

One binding feature of all arid zones in the world is aridity. Many times, the term drought and aridity are used incorrectly. A drought is a departure from average or normal conditions in which shortage of water adversely impacts the functioning of ecosystems, and the resident population of people. Aridity refers to the average conditions of limited rainfall and water supplies, not to the departures therefrom. In general, arid zones are characterized by pastoralism and little farming but there are always exceptions.

The arid zones of the world vary greatly from one another as far as their geomorphological features are concerned. The plains, pediments, rocky and semi-rocky land forms including small to high mountainous terrain, and deeply incised ravines in arid zones, display sharp changes in to physiography and slope. Many of these land forms are covered by unstable sand dunes or sand sheets. Sand also inundates arable crops, grazing lands, silvipastures, communication networks such as roads and railways, and cities and villages. The geomorphological features of land also influence soil formation and its characteristics. Water-holding capacity and ability to supply nutrients are of primary importance to the soils of arid zones. Soil depth largely governs the amount of water that can be held in a soil profile. In arid zones, the depth of soils exhibits tremendous variation. In many places the soils are quite deep, although in a number of places the depth of soil is often limited by the presence of a hardpan layer, which restricts water-holding capacities. These hardpans, which consist of various material, depending upon the action of climate and vegetation on parent rock, can be more or less continuous and occur between 5 and 60 cm below the surface. In general, soils in arid zones are characterized by the leaching of nutrients and intensive weathering of minerals, and therefore, the natural fertility of such soils is low.

Water is a scarce commodity in arid zones. Much of the rainfall is lost by evapotranspiration, and as a result, groundwater is recharged only locally by seepage through the soil profile. However, it is a common phenomenon in arid zones of the world that groundwater is frequently used at rates that exceed recharge. Moreover, the water that is available for use in many arid areas of the world is affected to varying degrees by salinity. Mineralization of groundwater resources is also a common problem. The reasons for mineralization include evaporation from water surface, fossil brines from ancient river courses and lakes, and airborne salts deposited by precipitation, and also in the form of dry fallout.

In arid zones, vegetation is typically sparse, and is comprised of perennial and annual grasses, other herbaceous plants, shrubs and small trees. The native plant species have adaptations that enable them to reproduce, grow and survive in the most inhospitable edaphoclimatic conditions. Some plants have evolved special root systems, while other have unique leaf characteristics that allow them to withstand prolonged periods of drought. Many woody species simply lose their leaves when soil moisture conditions become too dry. In general, the plant species of arid zones have xeromorphological leaf structures, physiological control of transpiration and metabolism, moisture and nutrient storage organs, and thorns. Such specialization becomes more pronounced in hyper-arid situations, and with decrease in aridity such specialization in plant structure and function also tends to decrease.

The number of tree species is very limited in arid zones, and in general, they are very slow growing due to limitations of environmental conditions, but nowhere in the world are they so intricately associated with the life of human beings as in arid areas. To evade or minimize the adverse affects of frequent droughts, the native peoples in arid zones have often developed production systems in which woody perennials have a very important role, both from a productivity as well as a resource conservation point of view. Their centuries-old experiences, under diverse socioeconomic and cultural conditions, were passed from generation to generation and have established well-contained systems of production (silvipastoral/agrisilvicultural/agrisilvipastoral/livestock husbandry) which accrue maximum benefits from their woody component(s). If arid zones are looked at from the angle of forestry development, it appears that this is basically concerned with the management of trees and shrubs which are either native to a particular arid zone, or have been introduced, especially for conservation purposes. However, concern for trees and forests has increased in arid zones as it has for any other region in recent years. This concern has been fuelled mostly by the disappearance of large quantities of woodlands and trees from such fragile ecosystems in many countries of world.

Many peoples all over the world are now very concerned about trees. People whose way of life depends on daily easy access to tree products are most directly affected by loss of trees, and this is particularly true in the complex environmental, socioeconomic and cultural conditions of arid zones. This article is concerned with the tree species of hot arid zones of India, and to clarify the subject, brief accounts are included of individual native and introduced species in Section 5. These are designed in such a way that an idea is conveyed about various ecological aspects of these tree species, and the importance of tree components in life support systems of arid zone. The article starts with the brief account of the arid zones of world in Section 2, goes on address the Indian hot arid zone itself in Section 3, and in Section 4, discusses the woody vegetation ecology of the Indian hot arid zone.

## **2. Arid Zones of the World**

### **2.1 Classification**

According to the world atlas of desertification produced by the United Nations Environment Programme (UNEP), the ratio of P/PET (precipitation/potential evapotranspiration) is useful in determining the aridity index (AI), and by using this index, the arid zones of world are delineated. When the value of P/PET is  $<0.05$ , the environmental condition is considered hyper-arid, and when the same value ranges between 0.05 and  $<0.2$ , the environment is considered arid. The areas with a P/PET value from 0.20 to 0.50 are considered semiarid. In this article only consider hyper-arid and arid environments are considered; these are jointly referred to as arid environment, because throughout the world, semiarid conditions are different in the nature of their climate, land, vegetation, and socioeconomic- and cultural set ups and problems.

The hyper-arid zones consist of acute dry areas, where vegetation is either absent or represented by a few scattered shrubs. The total annual rainfall is quite low, rarely exceeding 100 mm. In most arid zones, the native vegetation is sparse, and comprises

annual and perennial grasses, other herbaceous plants, shrubs and small trees. There is very high variability in rainfall, with the annual total ranging from 150 to 300 mm, or sometimes slightly more.

## 2.2 Distribution

Arid zones are located in almost all the continents of world (see Figure 1). In North America, arid zones are found in the southern US and Mexico, and in South America they are located in Brazil, Argentina, Chile, and in some other countries. In Africa, substantial parts of Saharan Africa, Ethiopia, and Namibia, are classed as arid environment. In Saudi Arabia, Iran, and other West Asian countries, large areas have an arid environment, and in South Asia arid zones are located in parts of the Indian subcontinent. Australia has a large arid zone area. In addition to the hot arid zones, larger parts of Tibet and Mongolia; parts of China, and countries of the central Asian region (especially the republics of the erstwhile USSR), and extreme northern parts of India and Pakistan, have cold arid environments. Cold arid ecosystems have unique features and unique problems.



Figure1 Arid zones of the world

Details are given of the area-wise distribution of arid zones in different continents of the world are given in Table 1). Of the total world area of arid zones, Africa accounts for 46.1%, followed by Asia (35.5%). Europe has the minimum area of arid zone. Of the total arid zone area, the hyper-arid zone accounts for 38.4%, and the arid zone for 61.6%.

Continent	Area (million hectares)	Percent of total
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Africa	1175.5	46.1
Asia	903.0	35.5
Australia	303.0	11.9
Europe	11.0	0.4
North America	84.6	3.3
South America	70.2	2.8
<b>Total</b>	<b>2547.3</b>	<b>100.0</b>

Table 1. Extent of the arid zone in different continents of the world

## 2.3 Major Vegetation Types

To classify the broad vegetation patterns of the arid zone, the major delineations are usually characterized in terms of rainfall amount and pattern of occurrence. On this basis, three major vegetation patterns have been identified.

### 2.3.1 Desert

Here the term desert is used in its narrowest sense to classify land where vegetation is virtually absent, except for near water courses. Ephemeral grasses and herbs can appear after rain showers. Such vegetation patterns are observed in the areas having rainfall of less than 100 mm per year.

### 2.3.2 Semi-Desert

In this region vegetation comprises a mixture of grasses, herbs, shrubs up to 2 to 3 meters in height, and short trees. Semi-desert grasslands occur in the areas where geological erosion has been less intense, and soils are capable of absorbing limited rainfall. The resulting vegetation pattern is a uniform cover of mixed grasses and herbs. In many arid areas where rainfall is a little higher, or sometimes along drainage sites/catchment areas, scattered trees and shrubs are found in relatively greater abundance. Open communities of succulent plants and grasses may or may not be present. In general, semi-desert vegetation is characterized by plants with extreme reduction of leaves, good development of storage tissues, and the presence of thorns and spines. The rainfall in the areas where semi-desert vegetation is found often varies from 100 to 300 mm/yr.

### 2.3.3 Low Rainfall Savanna

The vegetation in this region includes a mixed type consisting of grasses and herbs with shrubs, trees, or both. The trees and shrubs often have flat umbrella-like crowns. The crowns do not form a closed canopy, but leave large openings in which herbs, grasses and shrubs grow, although bare spots occur as well. The shrubs and trees do not provide sufficient shade to prevent the development of ground flora, especially grasses. This kind of woodland savanna or parkland is typical of arid tropics with a long hot and dry period, followed by a short rainy period. Such a pattern of vegetation development is found commonly in arid zones where rainfall is around 250–350 mm/yr.

## 2.4 Critical Problems

Throughout the arid zones, there is no dearth of problems, but rapidly increasing desertification (some call it land degradation) is a problem of worldwide dimension. Land degradation appears to be more of a descriptive term than desertification, as it better describes the process of Aeolian and fluvial erosion, soil salinization, and loss of vegetation cover. It helps in clarifying relationships among climate, topography, soil structure, land use, hydrology, and vegetation. Throughout the arid zones of the world, the major factor responsible for land degradation is soil degradation. At the world scale, the GLASSOD database indicates that in arid zones, more than 60% of soil degradation is caused by wind erosion, with anthropogenically induced water erosion accounting for 8% percent of the phenomenon. At the global level, 349.6 million hectares of land in arid zones are affected by a light to moderate degree of soil degradation, and 42.9 million hectares have strong to extreme soil degradation (see Table 2). Besides wind and water erosion, over- grazing, high magnitude agricultural degradation activities, over exploitation of vegetation for domestic use, e.g. fuel; and faulty land use are other factors responsible for ever increasing land degradation in arid zones.

Continent	Light and Moderate	Strong Extreme	Total
Africa	150.2	22.3	172.5
Asia	131.9	18.8	150.7
Australia	48.9	0.0	48.9
Europe	4.8	0.0	4.8
North America	6.3	1.6	7.9
South America	7.5	0.0	7.5
<b>Total</b>	<b>349.6</b>	<b>42.7</b>	<b>392.3</b>

Table 2. Degree of soil degradation in the arid zones of the world (million hectares)

The links between land or soil degradation and vegetation in arid zones are complex. Vegetation and soils display differing resilience to disturbance. Although in arid zones vegetation communities can be readily disturbed and degraded, recovery rates are very slow in comparison with those of other ecoclimatic conditions. Vegetation in arid zones displays a sensitivity to natural climatic variability. Decreased production and an ability to lie dormant are two strategies displayed by arid zone plants for survival at times of moisture deficiency. Although an adequate database is not available, two useful relationships between soil degradation and vegetation can be determined. First, vegetation cover may help to indicate the vulnerability of a particular habitat to soil degradation, and second, vegetation cover or community type or plant species may indicate that soil degradation has occurred or is taking place.

## 3. The Indian Hot Arid Zone

### 3.1 Location and Distribution

The hot arid regions of India lie between 24° and 29° N latitude, and 70° and 76° E longitude, covering an area of 31.70 million hectares, and involving seven states: Rajasthan, Gujarat, Punjab, Haryana, Andhra Pradesh, Karnataka, and Maharashtra (see

Figure 2). An area-wise break up of hot arid regions is presented in Table 3. In total, 11.8% of the country is under a hot arid environment. The arid regions of Rajasthan, Gujarat, Punjab, and Haryana together constitute the great Indian desert, better known as the Thar Desert. Thus the Thar, which accounts for 89.6% of the total hot arid regions of India forms the principal hot arid zone of the country.

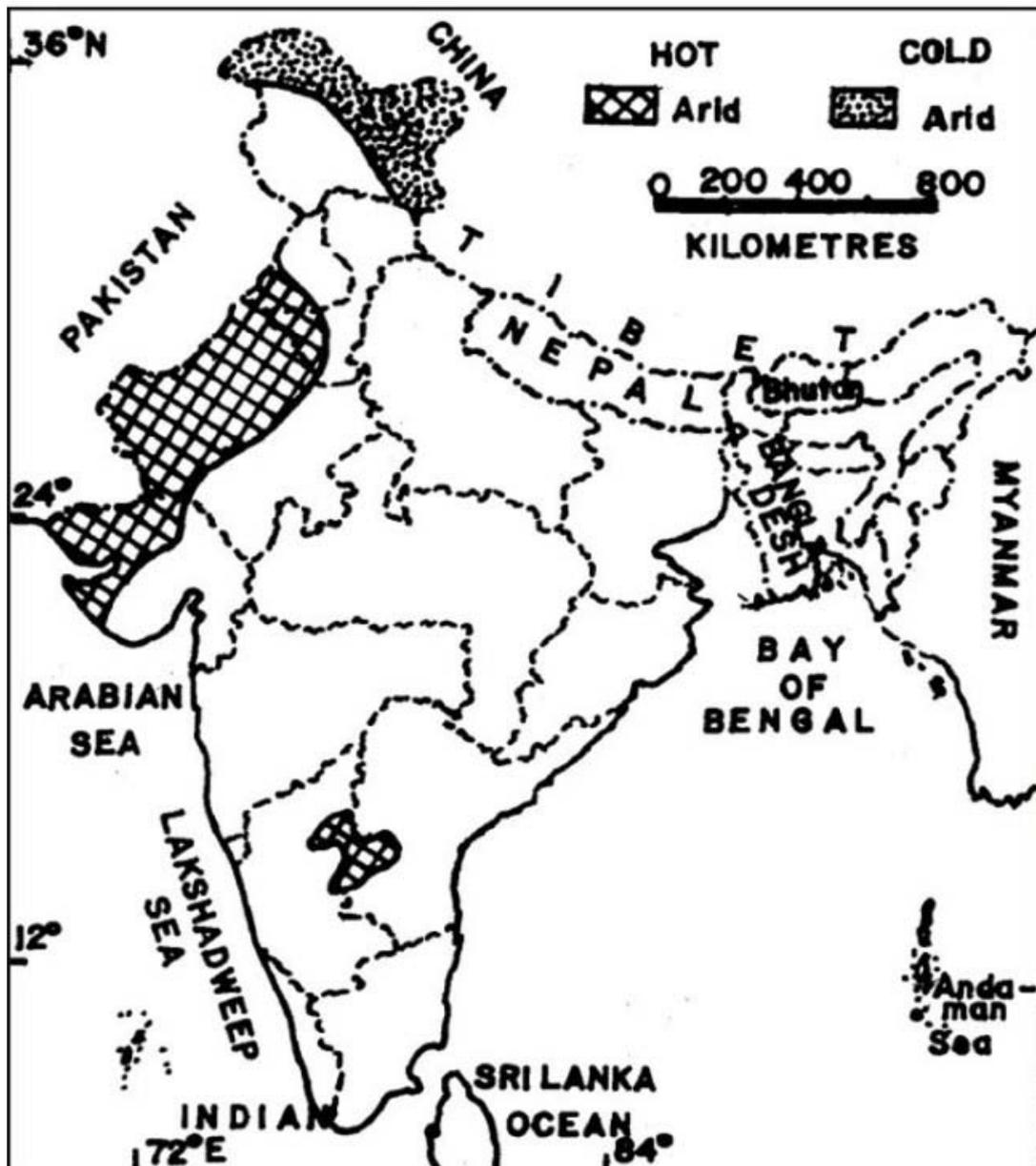


Figure 2. The arid zone of India

State(s)	Area (million hectares)	Percent of total
Rajasthan	19.61	61.00
Gujarat	06.22	19.60
Punjab and Haryana	02.73	09.00
Andhra Pradesh	02.15	07.00

Karnataka	00.86	03.00
Maharastra	00.13	00.4
<b>Total</b>	31.70	-

Table 3. Distribution of arid regions in different states of India

### 3.2 Physiography

The Thar Desert is spread over twelve districts of western Rajasthan, Kutchh and the Saurashtra region of Gujarat, and the southwestern parts of Haryana and Punjab states. A major part of it occurs between the Aravalli Ranges on the east and southeast and the Thal Desert of Pakistan (the Thal Desert is simply the western extension of the Thar), which spreads up to the Sulaiman Kirthar ranges in the extreme west. The Thar extends for 640 km from northwest to southeast, with an average width of 300 km from east to west. In the east of Jaisalmer, the desert forms a lowly elevated plateau, 150–325 m above sea level, with numerous rock masses jutting out of the desert sand.

The only river of some significance in the Thar Desert is the Luni. This river rises in the Aravalli hill range near Ajmer, and after an initial west-southwesterly course towards Barmer, it flows southwest until it drains into the northeastern corner of the western Rann of Kutchh. The principal tributaries of the Luni River are the Lilri, Raipur Luni, Guhiya, Bandi, Sukari, Jwai and Jojri. Neither the Luni River nor its tributaries are perennial. Because of lack of adequate river and drainage systems in the Thar, there are no well defined channels for the discharge of water in the entire region.

Therefore, during the monsoon, even with meager rainfall, the flowing water has a tendency to accumulate in innumerable freshwater tanks and reservoirs, which cater to the local needs of water for at least some months after the monsoon. The Kutchh region is surrounded towards the north, east and south, by an extensive almost level marshy land separating this huge land mass from the mainland of the subcontinent; this is known popularly as the Rann of Kutchh.

In general the Thar Desert has been divided into four major landform units: (i) the dunes and sheet deposit; (ii) comparatively dune-free area with rock outcrops; (iii) distinct rock outcrops; and (iv) the Luni basin, comprising alluvial deposits of the past river course. The arid areas of peninsular India are mostly sandy plains, with small rocky-gravelly hilly terrain found in a few pockets.

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## Contact Details for Information on Arid Zone Trees and Tree Seed Clearing Houses

1. Arid Land Information Centre, The University of Arizona, 1955E.6th St., Tucson, AZ 85719-5224, US. Fax +1(520) 621 3816
2. Australian Tree Seed Centre, Bank Street, Yaralumla, ACT 2600, Australia. email atsc@ffp.csiro.au.

3. Central Arid Zone Research Institute, Jodhpur 342003, India. Fax + 91 291 740706; email jctewari@cazari.raj.nic.in or aksharma@cazari.raj.nic.in.
4. Desert Legume Program, 2120 East Allen Road, Tucson, Arizona 85719, US. Fax (520) 621 1296; email mjohnson@ag.arizona.edu.
5. International Centre for Research in Agroforestry (ICRAF), United Nations Avenue, P.O. Box 30677, Nairobi, Kenya. Fax 2542 521001; email icraf@cgiar.org. ICRAF produces the Agroforestry Database and Tree Seed Suppliers Directory on CD-ROM.

### **Biographical Sketches**

**Arun K. Sharma** is a Senior Scientist (agroforestry) who has been working on arid zone agroforestry over the last 10 years. His main area of research is the conservation of rainwater for and by agroforestry, and the development of self sustainable (no external input required) agroforestry models, duly considering the time-tested traditions for natural resource conservation in the arid zone. Technologies developed so far include: Integrated microcatchments for tree establishment in the arid zone; Self sustainable agrihorticulture systems for the arid zone; and Domestication of medicinal plants in arid zone agroforestry. Sharma is presently working as Principal Investigator of a multi-location project on "Production enhancement in gypsiferous and impeded soils of arid zone."

**Dr. J. C. Tewari** is presently working as a Senior Scientist (Forestry) at CAZRI, Jodhpur. Dr. Tewari started his research career as Research Associate in the Department of Botany, Kumaun University, Nainital, India, where he worked extensively on the vegetation ecology of the Central Himalaya. He served later as a lecturer of Forest Ecology. Dr. Tewari moved to CAZRI and began working on arid zone forestry and agroforestry 16 years ago. He has more than 100 research papers and four books to his credit.