Geo Factsheet

Number 24

The Causes Of Aridity

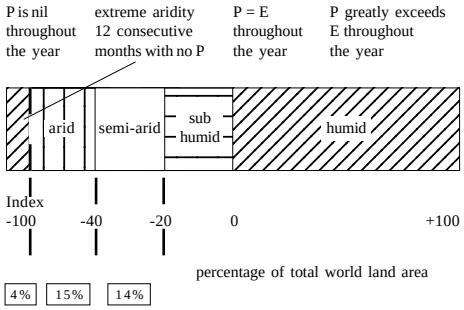
Aridity is basically a lack of water, so that an arid area is characterised by small amounts of precipitation, occurring infrequently, unreliably, and often in the form of heavy downpours. Consequently, arid areas can be linked with the occurrence of deserts since the conventional definition of a desert is an area receiving less than 250mm of rainfall per year.

A more precise definition of deserts and arid areas can be produced through measuring water balance. This is based on the relationship between;

(1) input of water as precipitation - P
(2) output of moisture resulting from evapotranspiration - E, and
(3) changes in water held in the ground.

In arid areas there is high potential evapotranspiration since the volume of water that could be lost through evaporation and transpiration is greater than the volume of water which is actually available. The relationship between precipitation and potential evapotranspiration can be used to produce an aridity index (Fig 2). Using such an aridity index 14% of the globe can be seen to be semi-arid, 15% arid and 4% extremely arid.

Fig 1. Aridity Index



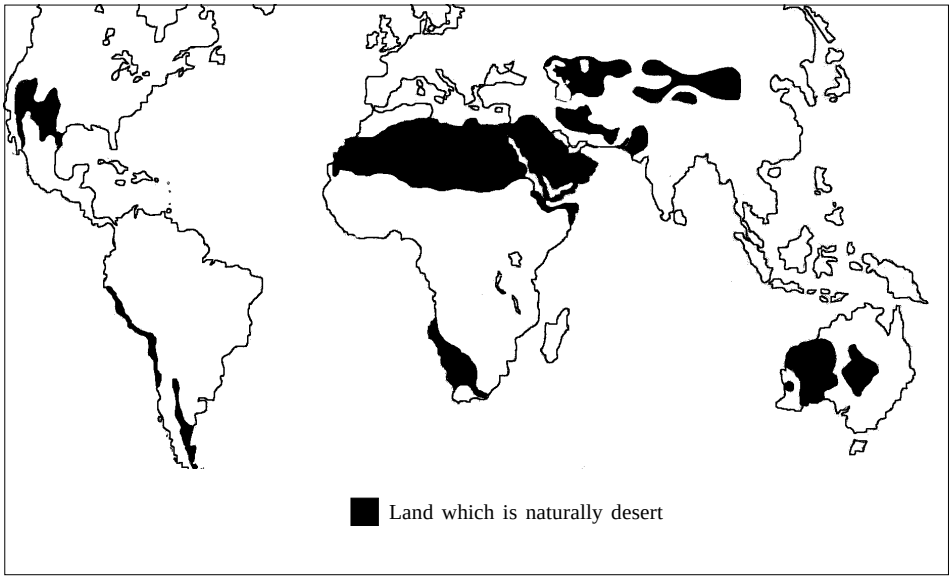
Causes of Aridity

There are four major factors associated with aridity and the subsequent formation of deserts. These factors generally interact together to produce arid conditions, although in many cases one factor may be dominant.

1. Atmospheric high pressure

Most deserts lie in the centre or on the west coast of continents, between 15° and 30° north or south of the Equator. Air which has been warmed at the equator rises, cools and eventually descends at 30° north and 30° south of the equator. This descending air warms and, as a consequence, its water-holding capacity increases.

Figure 2. Global distribution of arid areas



In turn, this results in very low atmospheric humidities at these latitudes, making cloud formation or rain unlikely.

2. Rainshadow

This is the effect produced by tall mountain ranges (known as orographic belts). The windward slopes of such barriers will be wetter than the leeward slopes, which may therefore experience an arid climate. Orographic effects of this kind are responsible for the relative aridity of the western slopes of the Rockies and the Andes and, for example, the eastern slopes of the Cascade mountains in Washington and Oregon. As the air rises on the windward slopes of the mountains, pressure decreases and it cools, resulting in condensation, cloud formation and rain. As air then descends on the leeward sides of these large, mountainous regions, pressure increases and the air is warmed, thus preventing condensation. This effect is particularly pronounced when mountain ranges are on the east of a continent, such as in Australia. In addition, it is thought that the Gobi Desert of central Asia, which is largely north of the sub-tropics, has formed due to air descending from the Himalayas.

3. Cold ocean currents

Several deserts lie along western coasts where, due to the action of circulating wind currents, there is upwelling of cold sea water. This cools the passing air masses, reducing the amount of water that the air can hold, so limiting the amount of precipitation which can be held. The Atacama desert on the west coast of South America and the Namib desert on the west coast of Africa have formed in this way.

4. Continentality

As an air mass moves over a continent it will lose moisture as precipitation. Equally the air will take up very little moisture due to the low evaporation rates over land surfaces. This means that areas in the centre of continents have very little rainfall simply because the air has become much drier. This effect is best seen on large continents such as Australia, North America and Asia.

Exam Hint *- Common questions on this topic involve students being asked to explain the precipitation characteristics of deserts and to suggest an explanation for the presence of a desert in a specific region after studying a map.*

Desertification

Arid areas are very unlikely to be completely devoid of life, since organisms evolve to exist within these difficult environments. However globally, desert areas are increasing in size, a process known as desertification.

The United Nations Conference on Desertification in 1977 defined desertification as, 'the destruction of the biological potential of the land, that can ultimately lead to desert-like conditions'. It can literally be considered as 'the making of deserts'. Desertification is now considered a direct threat to over 250 million people world-wide and, over the last 25 years, it has become increasingly apparent in the semi-arid regions of the world.

Primary causes of desertification

According to many observers, the underlying primary causes of desertification are socioeconomic; people who do not own land or who have little security of tenure are reluctant to implement long-term soil conservation techniques. Highly subsidised agricultural exports from developed countries depress the world market price of many staple agricultural crops and this encourages developing countries to expand cash crop agriculture, often at the expense of the small, subsistence farmer who, in turn, commonly see themselves forced to slash and burn, overcultivate or overgraze to expand production.

The relationship between the primary and secondary causes of desertification are summarised in Table 1.

Characteristics of Desertification

- *Accelerated soil erosion by wind and water.*
- *Increasing salinisation (build up of salts) of soils and near-surface groundwater supplies.*
- *Reduction in soil moisture retention.*
- *Lowering of water table*
- *Increase in surface runoff and streamflow variability.*
- *Reduction in species diversity, plant biomass and overall productivity of the ecosystem.*
- *Impoverishment of the human communities dependent on these ecosystems.*

Table 1. Secondary causes

Climatic factors	*Soil and water factors*
Rainfall variability *Periodic drought, often prolonged* ***Alternate wet and dry seasons*** *Death of annual vegetation* *Soils bare during first storms* ***Storm rainfall*** *Leaching of nutrients* *High proportion of erosive rain* *High water loss through run-off* ***High temperatures*** *High evapotranspiration* *Rapid decomposition of organic matter*	***Low clay content*** *High erodibility* *Crusting* *Nutrient poor* *Low water retention* ***Semi arid zone*** *High soil temperature* *Low water retention* ***Humid zone*** *Acid soils therefore* *pH or aluminium toxicity* *High seasonal variation of rivers* *Low surface water availability and high evaporation*
Biological factors	***Social factors***
High disease and pest incidence *Low labour productivity* *Crop losses* *Low animal productivity* *Rapid weed growth*	***Uncertain tenure*** *Reluctance to invest in long-term improvements* ***Labour shortage*** *Male labour migration* *Women's excess burdens* *Child rearing* *Gathering of fuelwood*

Human activities

These relate to actions where land has been overused.

(a) **Overgrazing.** This is one of the main human activities contributing to desertification and occurs when herd sizes exceed the carrying capacity i.e. the number of cattle that can graze an area without long term damage occurring. If this carrying capacity is exceeded, a variety of serious detrimental effects can occur:

- Quality and quantity of vegetation is altered. Changes in species occur, with palatable grasses being replaced by drought-resistant species, which may be less able to bind soil together.
- Soil quality declines. The hooves of grazing animals compact the soil surface and break down the soil structure, increasing the likelihood of soil erosion by wind and rain storms.
- Health of animals decline. The decline in pasture area and quality affects the production of both meat and milk.

(b) **Overcultivation.** This may occur as a result of the pressure on agriculture to produce more food, either to support an increasing population, or to grow 'cash crops' for sale in city markets or for overseas export. Alternatively, it may be through the cultivation of soils that are unsuitable for the growth of crops. The most significant effect of overcultivation is the reduction in soil fertility which occurs when a plot is not allowed to recover its fertility because fallow periods are shortened. In this way, soil becomes exhausted, nutrients are lost and soil structure deteriorates. In turn this reduces crop yields and plant cover, leaving soils exposed to erosion.

(c) **Vegetation clearance.** Clearance, either for land preperation or as a result of fuelwood;

- Lowers the water table
- Removes a source of shade and food
- Leads to an increase in the burning of dung as a fuel source which would otherwise have been used for fertilising soils.

(d) **Salinisation and waterlogging.** Both of these problems are associated with irrigation schemes in arid areas which were designed to reduce the problems of unreliable rainfall. If irrigated land is not drained adequately, the groundwater levels rise in the soil and evaporation increases salt concentration in the soil. This

impairs plant growth and may even result in complete waterlogging with an upper salt crust. Table 2 indicates the global scale of the problem of irrigated land.

Exam Hint *- Good candidates should understand that loss of nutrients from soils in arid areas is usually greater than in more temperate climates. There are two reason for this. Firstly, the soils have a lower organic matter content than soils in more humid regions. Secondly, nutrients in these soils tend to be concentrated in the upper layers since there is little rainfall to leach them down the soil profile. Consequently, the soil which is lost during erosion is the nutrient-rich component.*

Table 2. Example of salinisation of irrigated land

Country	Areas of cultivated land under irrigation (million ha)	Percentage of irrigated land affected by salinisation
Australia	1.6	15-20
Egypt	2.5	30-40
Pakistan	15.3	35
USA	19.8	20-25

The effect of drought

A continued absence of expected rain will clearly cause desertification, since plants will wilt and die, and cultivation and livestock are severely affected. Drought can be broadly divided into three categories:

(i) **Meteorological droughts.** These occur when rainfall is significantly lower than would be expected for the time of year in a particular region. Generally, the larger the amount of rain expected, the shorter the period of deficiency which is termed a drought.

(ii) **Agricultural drought.** This is defined as a period of dry weather of sufficient length and severity to cause at least partial crop failure. Therefore , this is based on the amount of rainfall that is actually available to crops and whether this is sufficient for the growth of the crops.

(iii) **Physiological drought.** Plants which are growing in salt-rich soils will tend to lose water osmotically and will find it difficult to absorb water from the soil. This is termed physiological drought.

Since drought reduces vegetation cover it can lead to desertification. However, it is important to remember that in most arid areas, plants are well adapted to drought conditions and may survive very harsh conditions.

Exam Hint *- A good student must be able to understand the effects of desertification on particular areas of the environment, for example the changes that will occur in the hydrological cycle due to the changing conditions and the changing characteristics of the soils. Many students lose marks by failing to produce sophisticated answers which have drawn knowledge from different areas of the syllabus.*

Desertification and Climate Change

Arid areas frequently experience droughts, but their **periodicity** i.e. the time between consecutive droughts is very difficult to predict. The abnormal length of droughts in the 1970s and 1980s, for example in the Sahel region of Africa, has led to suggestions that arid areas are experiencing a significant climate change. In addition, the western United States, southern African and Australian arid areas have all shown pronounced warming this century. Both of these have been associated with the enhanced 'greenhouse effect'.

If the climate of arid areas is becoming drier, this obviously has very significant implications for the natural environment and the local human populations. Specifically, predicted increases in temperature are likely to have the effect of increasing potential evapotranspiration rates, thereby increasing aridity. However, climate change has yet to be proved and the significance of future global warming is difficult to assess, mainly due to the great natural variations in annual rainfall in these regions. In addition, even if temperature increases do occur, it is impossible to predict the actual effect. For example, rainfall may actually increase due to greater evaporation of sea water resulting in more water vapour in air masses which increases precipitation. The strength or otherwise of evidence for present-day climatic change will be the focus of a further Factsheet.

Exam Hint *- Many questions concerning aridity and desertification expect students to be able to discuss in detail the effects, particularly the hazards, posed by drought and climatic uncertainty. Such answers must cover a broad range of issues, including social, economic, health and environment.*

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This Geo Factsheet was researched and written by Jim Sharpe.

***Geo Press**, 10 St Paul's Square, Birmingham, B3 1QU*

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