CAIE Geography Pre-U

1A: Hot Arid and Semi-Arid Environments

Detailed Notes

Definitions, Classification and Distribution

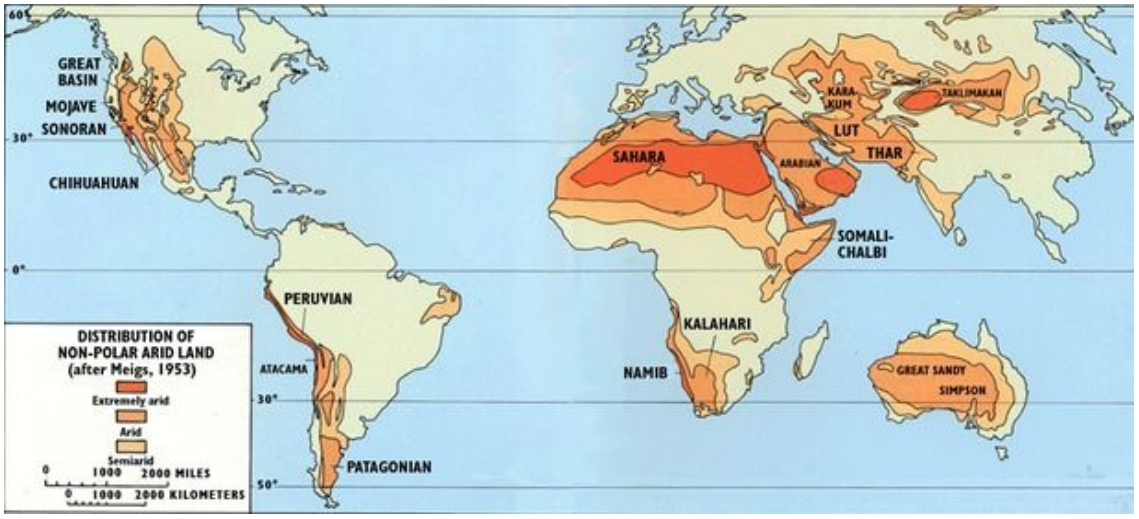
Meaning of aridity and the aridity index

Aridity is the lack of moisture, especially having insufficient rainfall to support most trees or woody plants. It is extremely dry, has low precipitation, and high rates of **evapotranspiration**.
The **aridity index** is the average annual precipitation divided by the annual potential evapotranspiration(the amount of evapotranspiration that would occur if there was sufficient water). It is divided into three categories:

- **Hyper arid** which has an aridity index of less than 0.05 and rarely exceeds 100mm of annual precipitation.
- **Arid** which has an aridity index of 0.05-0.2 and rarely exceeds 250mm of annual precipitation.
- **Semi-arid** which has an aridity index of 0.2-0.5 and rarely exceeds 500mm of annual precipitation.

Global distribution of hot arid and semi-arid areas

Mainly located on the west side of continents and mainly either along the **tropic of Cancer or the tropic of Capricorn**.



http://crimsonsandstourism.weebly.com/location.html

The concept of dryland environments

One of the ways of classifying arid environments is the use of the **Koppen classification system** which classifies based on the relationship between temperature and precipitation. The Koppen arid and semi-arid areas include:

- **BWh** which is a hot, dry desert with annual temperatures above 18°C such as the Sahara.
- **BShw** which is a desert which rains during the hottest months such as Mali.
- **BShs** which is a desert which rains during the coldest months such as North Africa.
- **BWn** which is an arid desert with coastal fog such as the Atacama desert.

Definition of desertification and the global distribution of desertified and desertifying areas

Desertification is the process of land **degradation** in arid and semi-arid regions as a result of various factors both climatic and from human activities.

Areas that are most at risk of desertification are those that surround existing deserts. Some of the most common causes are:

- Overfarming
- Removal of plants/deforestation
- Overgrazing
- Climate change
- Lack of precipitation
- Natural disasters

Past changes in the extent of aridity

Pluvials are periods marked by increased rainfall whereas **interpluvials** are those marked by decreased rainfall.

The **tertiary period** occurred 66 million to 2.6 million years ago and the **quaternary period** is the current and most recent period.

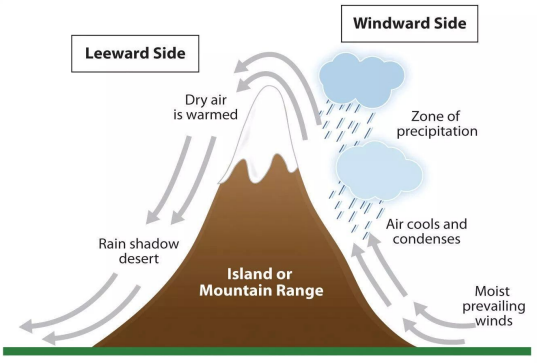
Scientists know that levels of aridity have changed due to various sources of evidence including:

- **Archaeological** such as rock paintings in current dry areas which show animals that now live in wetter climates. There are also ancient remains which show signs of water damage.
- Observing the **landscape and formations** that are present and how they were formed-some landforms that occur in arid areas could have only been formed when more water was present.
- **Biological** evidence such as the evolution of the horse, fossils and pollen analysis of plants that show that there are plant sediments in current dry areas which could only grow in wetter climates.
- **Ocean sediments** can be analysed for the ratio of Oxygen-16 and Oxygen-18 isotopes that were present in skeletons on the ocean floor.

Scientists predict that in the future, arid and semi-arid areas will become more prevalent and extensive. They will spread and expand due to land degradation resulting from human activity. For example, the **Sahara is advancing at a rate of 2km to 5km a year**.

Controlling factors: Climate and the hydrological cycle

Causes of aridity



- **Relief and the rain shadow effect**: Tall mountain ranges, such as the Andes, force air to rise on the **windward slopes** of the mountains, as pressure decreases and the air cools, condensation and cloud formation occurs and this produces rain. As the air descends on the **leeward sides**, pressure increases and the air is warmed which means that no

condensation occurs. This results in windward slopes being much wetter than leeward slopes and can cause arid areas to form on the leeward side.
https://peartreegeogblog.wordpress.com/2014/10/09/relief-rainfall-diagram/

- **Global atmospheric circulation**: Most deserts lie in the **subtropical high-pressure zone** where the air is subsiding in the descending limb of the **Hadley cell**. This causes dry stable air.
- **Cold ocean currents**: Several deserts lie on the western coasts of continents where there is an upwelling of cold water due to the circulation of wind currents. This cold water on the surface decreases the temperature of the overlying air mass and so reduces the amount of water it can hold. If the air mass blows over the land then this will result in drier conditions, an example of this is the **Atacama desert**.
- **Offshore winds**: If the prevailing wind blows from the land to the sea then it will carry low amounts of moisture. For example, the **Sahara desert** is located close to the Atlantic ocean, however, because the prevailing winds blow in a northeast direction, they have been blown across the African continent and so contain little moisture.
- **Continentality**: If the air mass moves over a continent it will lose moisture due to rainfall. It will not pick up much moisture due to low evaporation rates and so areas which are located in the centre of continents will have very little rainfall.

Characteristics of typical desert climates

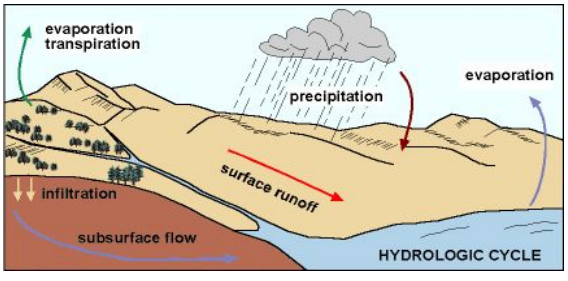
- **Temperature**: Temperature differences between night and day (**diurnal ranges**) are very high in desert climates due to low levels of cloud at night resulting in high amounts of heat loss and so cold nights. **Diurnal ranges can reach 15-22°C**. Annual temperature ranges depend on the latitude of the desert but most have low annual ranges.
- **Rainfall**: Although total annual rainfall in deserts is often low, most of the annual rainfall can occur in a short period of time. All arid and semi-arid areas have annual precipitation of less than 500mm. **Extreme rainfall events**, which is when there is more rain than the yearly average rainfall in a few hours, are common in most arid areas.
- **Evapotranspiration**: The total loss of water from evaporation from the ground and transpiration from plants. This is very high in desert areas due to high **insolation** and lack of cloud cover.

The hydrological cycle and water balance in hot arid and semi-arid environments

Even when rain does fall in arid areas, the effectiveness of this precipitation is very low due to:

- Rapid rates of **evaporation and transpiration**
- Bare surfaces which limit **infiltration**
- Low **interception** rates

This can cause flash floods whilst also not providing enough water for plant growth.
http://geology.isu.edu/wapi/EnvGeo/EG7_water/EG_module_7pt1.htm



The role of climate in influencing natural sources of water in hot arid and semi-arid environments

For aquifers to recharge, long steady periods of rain are more effective than short intense periods of rain. This allows the rainwater to infiltrate into the ground more effectively. Coastal mist and fog relies on the correct air masses to be present over the sea for it to form. Higher temperatures will cause greater evaporation of surface water as well as greater transpiration from plants. Higher temperatures can also make the surface harder and less permeable to water and so less water infiltrates into the aquifers.

Natural sources of water in hot arid and semi-arid environments

- **Aquifers** are underground sources of water as a result of permeable rock, rock that contains fractures or unconsolidated particles. Wells can be dug to extract this water for farming, mining or domestic use, however, due to high levels of extraction that is exceeding the recharging of these aquifers, the water levels are decreasing.
- **Coastal mist and fog** occur due to sinking air above a layer of moist air that has been formed over the sea. This causes a layer of mist or fog which can then travel over the land. This can be collected using large meshed nests with a collection system. **Chungungo, Chile** receives only 60mm of rain a year, however the installation of these nests collect and store 15,000 litres of water a day.
- **Dew** is water in the form of droplets that appear on exposed, thin objects in the evening or morning as a result of condensation.

Processes and landforms in hot arid and semi-arid environments

Weathering processes

Weathering is the process of breaking down a rock. It is the mechanism that leads to rock decomposition or degradation, and the production of sediment.
Low levels of precipitation with occasional flash flooding, low levels of plant protection, high temperatures and high diurnal ranges all increase the levels of weathering.

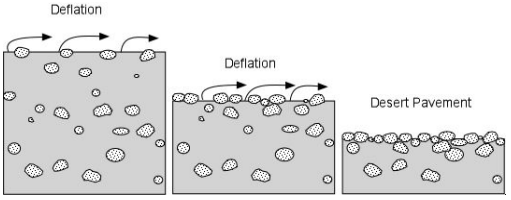
- **Frost shattering**: Water penetrates cracks or joints in the rocks. At night-time when temperatures drop, the water freezes and expands. This expansion puts pressure on the cracks causing them to split. During the day the ice melts and travels further into the cracks. This cycle repeats until the rock breaks and falls as scree or moraine.
- **Thermal fracture**: During the day, when it is hot, the rock expands. At night, when it is cold, the rocks contract which sets up stresses in the rock surface. The outer layer of rock flakes off because it contracts and expands at a faster rate.
- **Salt weathering**: High temperatures draw saline groundwater to the surface of rocks. Evaporation of this water leaves behind salt crystals. As this process continues, the salt crystals grow and this causes stresses in the joints and pores in the rock causing it to disintegrate.
- **Wetting and drying**: Water saturates the rock. This water can be from flash floods, seasonal rains, dew or coastal fog. The water causes clay minerals within the rock to swell. As the water evaporates the rock contracts again. This repeated contraction and expansion causes the rock to disintegrate.

- **Chemical weathering**: Decomposition of rock resulting from a chemical change.

Processes of erosion

Erosion is the wearing away and/or removal of rock particles and other materials by a moving force.

- **Deflation by the wind**: Loose and fine **regolith** (unconsolidated material that sits on top of the Earth) is removed by the wind. This leaves larger materials such as stones. Deflation can form stony desert surfaces, Reg, Gibber Plains or deflation hollows.
  http://earthsci.org/education/teacher/basicgeol/windes/windes.html



- **Abrasion/corrasion by the wind**: Wind-borne particles are driven against the rocks and act like sandpaper. This process is confined to a couple of metres above the surface as the particles cannot be carried up any higher. The rate of abrasion/corrasion depends on the strength of the rock and also on the velocity of the wind.
- **Abrasion by water**: Sediment carried by the water grinds against and wears away the bed and bank of the channel.
- **Sheet runoff by wate**r: After torrential rainfall, discharge in the channels is high which causes lots of erosion to occur.

Processes of transportation

Factors influencing transportation include:

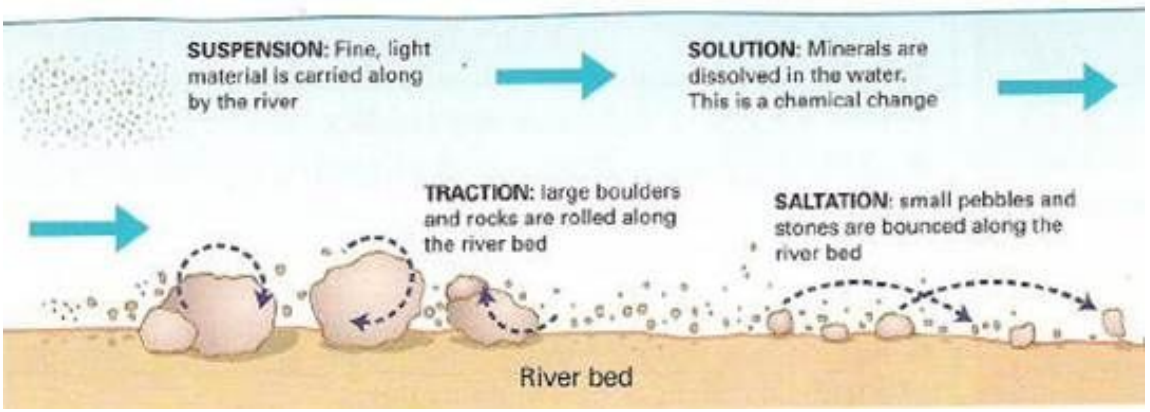
- Amount and type of vegetation cover
- Wind speed, duration and direction
- Degree of turbulence
- Nature and size of surface material

Types of wind transportation include:

- **Suspension** where particles less than 0.15mm such as silt or clay are carried in the air.
- **Saltation** where particles between 0.15mm and 0.25mm are moved in a series of small leaps.
- **Surface creep** where particles are greater than 0.25mm are rolled or pushed along the ground.

Types of water transportation include:

- **Suspension** where very fine particles of clay and silt are dislodged and carried by the turbulence in the river.
- **Solution** where soluble material is dissolved in the running water and removed in solution due to the acids in the river.
- **Bedload saltation** is where pebbles, sand and gravel are temporarily lifted up by the current and bounced along the bed in a hopping motion.
- **Bedload traction** is where the largest cobbles and boulders roll or slide along the bed.



https://sites.google.com/a/kgv.hk/kgv-gcse-geography/home/river-processes-and-pressures

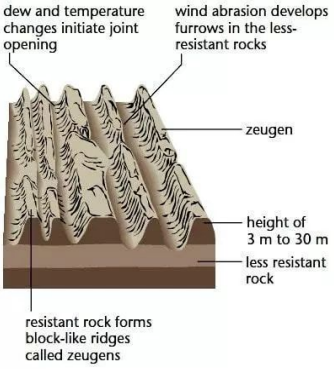
Landforms and landscapes of the past and present

Landscapes

- **Mountain deserts** are uplands in arid and semi-arid environments and can contain lake basins, salt flats, rivers and floodplains. The bedrock is exposed and the slopes are steep.
- **Stony deserts** are plains and plateaus scattered with rock fragments known as **Reg.** An example of a stony desert is the **basalt lava flow of the Syrian-Jordanian desert.**
- **Sandy deserts** contain erg dunes and sand 'seas'. This is what most people imagine when they think of a desert.
- **Shield deserts** are bare rock plateaux surfaces known as **hamada.**

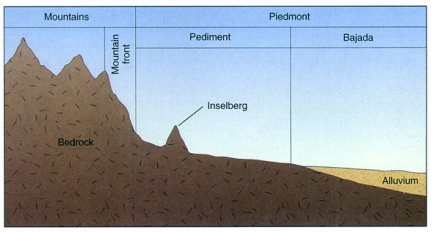
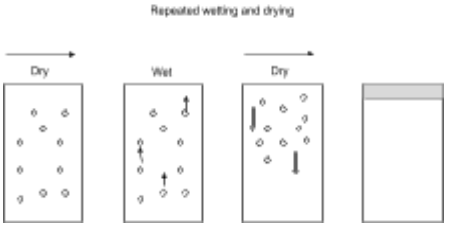
Wind erosion landforms

Landform	Explanation	Picture/diagram
Deflation hollows	A large, enclosed, surface depressions that were created by the removal of loose particles by the wind in large quantities. They collect runoff and can form salt lakes. The **Qattara Depression** in Egypt is the largest.	 https://commons.wikimedia.org/wiki/File:Bilutu_Peak.JPG

Ventifacts	Cobbles or pebbles which have been shaped by sand carried in the wind. This causes it to have smooth sides that are separated by sharp edges. The number of smooth sides depends on the number of different prevailing winds that have blown over the area.	http://www.sandatlas.org/ventifacts-and-dreikanters/ 
Rock pedestals	Mushroom-shaped rocks that occur where an isolated rock has been eroded more rapidly at the base.	 http://claremontspartans.blogspot.com/2011/10/rock-pedestal.html
Zeugen	A narrow ridge of land that has a protective cap of rock above it. Due to the horizontal layering of rocks, there is increased **corrasion** at lower levels.	 https://www.revision.co.zw/yardangs-zeugens-and-rock-pedestals/
Yardangs	Sculptured rocks which are streamlined, steep-crested, linear ridges of clay, rock or silt. They are caused by **abrasion** and small amounts of **deflation.** The rock layers are arranged vertically forming parallel rills or troughs.	 https://www.smithsonianmag.com/smart-news/what-yardang-180951461/

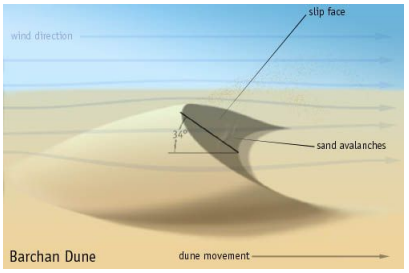
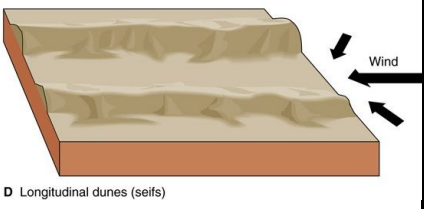
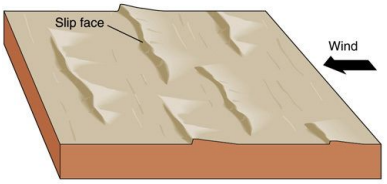
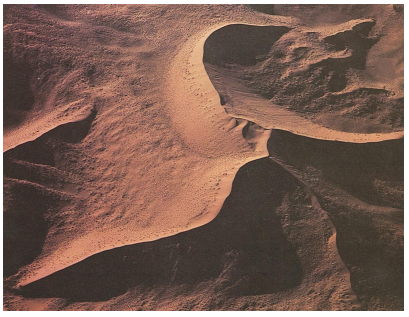
Water erosion landforms

Landform	Explanation	Picture/diagram
Wadis	Dry river beds which form temporary channels after periods of rain. They have steep sides and a wide floor. They are formed by **flash floods** which widen the **rills** and **gullies** then streams of water widen these **gullies** into **wadis**	 https://commons.wikimedia.org/wiki/File:Wadi_Qelt.JPG
Canyons	Desert gorges and are much deeper versions of wadis. They are formed by heavy rainstorm events which result in flash floods. High water erosion is combined with tectonic uplift to form canyons. An example of this is the **Grand Canyon in the Colorado Plateau.**	 https://commons.wikimedia.org/wiki/File:USA_09828_Grand_Canyon_Luca_Galuzzi_2007.jpg
Mesas	Elevated areas of land with a flat top and sides that are steep. They are formed by a **tectonically uplifted** horizontally layered rock which then undergoes **weathering** and **erosion**. This is called **differential erosion**.	 https://en.wikipedia.org/wiki/Mesa
Buttes	Were once part of a **mesa** or a **plateau**. They are an isolated hill with vertical sides and a small flat top. A protective cap of resistant rock protects the underlying rock from erosion.	 https://commons.wikimedia.org/wiki/File:West_Mitten_Butte_in_Monument_Valley.jpg

Pediments	Gently sloping erosional rock surfaces which forms an angle of less than 7°. They are found at the base of mountain ranges or cliffs and are formed by the parallel retreat of steep slopes of a mountain front.	 FIGURE 12.4 Profile from mountain into valley, showing the mountain front and the piedmont, with pediment, inselberg, and bajada. https://www3.nd.edu/~cneal/PlanetEarth/Lab-Deserts/Erosional.html
Arroyos	Dry riverbeds or seasonally active creeks. They are filled with water after heavy rainfall and dry up during dry periods. They are formed by **flash flooding**.	 https://cmapspublic.ihmc.us/rid=1J6PBKZNS-2DPRX97-176N/1J6CVKPJXISZ59TMI4S7/image
Inselbergs	**Isolated relic hills** which are rounder versions of **mesas or buttes.** They are formed by deep **chemical weathering** which occurs in the rock and the material is then carried away by water. The rock is then isolated by **differential erosion**.	 https://en.wikipedia.org/wiki/Inselberg
Surface crusts	Extensive areas of flat desert surfaces which are covered by a hard crust of fine material which reduces infiltration. It is formed wind **deflation** and the **selective sorting** of rock materials by the presence of subsurface water. Caused by **cycles of wet and dry periods**. When it is wet stones are pushed upwards and when it is dry particles are removed by the wind and also fine particles move downwards filling the gaps created by the movement of stones.	

Wind deposition landforms

Dunes are formed by the deposition of fine materials. This occurs when the wind speed decreases so that it can no longer carry the material. This often occurs where there is vegetation, a rock or other obstacle which slows the wind on the leeward side.

Landform	Explanation	Picture/diagram
Barchan/crescent dunes	Relatively small individual crescent-shaped dunes which point downwind. They are formed due to a dominant wind direction and a limited supply of sand and are highly mobile.	https://en.wikipedia.org/wiki/Barchan 
Seif/linear/longitudinal dunes	very large sand dunes which develop from **barchan/crescent dunes.** This is due to the elongation of one of the horns caused by a constant switching in the direction of the prevailing wind.	 D Longitudinal dunes (seifs) https://en.wikipedia.org/wiki/Dune#Parabolic
Transverse dunes	Look like ocean waves. They are formed by a steady trade wind in a constant direction. They are stabilised by vegetation.	 B Transverse dunes https://en.wikipedia.org/wiki/Dune
Star dunes	Pyramidal in shape and the tallest of all the dunes. They are formed by strong winds which blow from multiple directions. The largest of these is **Dune 7 in Namibia which is 383m high.**	 https://commons.wikimedia.org/wiki/File:Star-dune.jpg

Draa dunes	Sequence of large **star dunes** which form a ridge.	 https://en.wikipedia.org/wiki/Merzouga

Water transport and deposition landforms

- **Alluvial fans** are formed when water carrying sediment reaches a lowland plain or a basin. This causes the water to slow down and spread out. The sediment is deposited with the lightest being deposited the furthest away.
- **Bajadas** are a series of **alluvial fans** that join together. They are formed when multiple **wadis** arrive at the mountain front.
- **Playas** are salt lakes and are formed when **depressions** are occupied by shallow, ephemeral saline lakes with no surface outlet. An example of a **playa** is **Utah's great salt lake in the Great Basin desert.**
- **Salt flats** are flat expanses of ground which is encrusted with salt crystals and other minerals. It is formed when water from a salt lake evaporates. An example of this is **Badwater Basin in Death Valley.**
- **Washes** are the drainage areas in desert terrains. They are dry beds of sandy soil and are some of the only areas in deserts where water is able to penetrate back into the **aquifers.**

Human activity and its impacts on hot arid and semi-arid environments

Human interaction with hot arid and semi-arid environments

Societies living in these environments have to deal with infrequent and unpredictable rainfall, poor soil quality, low levels of vegetation and grazing pastures. Many societies overcome this by adopting a **nomadic lifestyle**. This means they are always moving depending on the availability of water and pastures. Some societies have adopted a **semi-nomadic** way of life where they move with their flocks and herds but when it reaches harvest time they set up their tents near villages and take advantage of the high levels of supplies. However, due to decreased availability of water and increasing desertification, many people have undergone the process of **sedentarisation** where they settle down in villages, towns or cities.
See **case studies** for detailed examples of the Tuareg, Maasai and Fulani and how they have been impacted in the last 50 years.

The opportunities and constraints for human activity

- **Climate:** provides a continuous growing season due to high amounts of sunshine however there are low levels of water.
- **Alluvium deposits:** provide **nutrient-rich fine soils** which can warm up quickly, however, they are prone to wind erosion and also flash floods.

- **Hydroponics:** can be used as an alternative to regular farming due to lower use of water although it is very expensive.
- **Advanced irrigation systems:** these include **dams and irrigation channels** so water can be obtained where it is needed. However, the large surface area of water which is present due to dams increases the level of evaporation so a lot of water is wasted.
- **Natural water sources:** oases, aquifers and ephemeral rivers can provide water to the local populations, however, due to climate change and overuse these sources are becoming less abundant.
- **Desalination:** Mainly used in rich countries due to the high cost. Removes salt from seawater so it can be used.
- **Mining:** Arid and semi-arid environments can contain **rich mineral resources** which can provide jobs in desert areas and help to improve local services, infrastructure and amenities. However, it uses a large volume of water, removes vegetation and waste produced can contaminate the area and natural water sources.
- **Tourism** provides economic benefit to the area and country whilst encouraging the improvement of infrastructure. These environments, however, are very fragile and have a low **carrying capacity** and are very vulnerable to human activity. Local cultures may also become **commercialised** for the tourism industry.
- **Renewable energy:** If just **0.3% of the Sahara desert** was used for a solar plant, it would provide all of Europe with clean renewable energy. This is difficult though because windblown sand covers the panels and transmission lines will be hard to build.

The contribution of humans to desertification

- **Overgrazing** of animal herd removes native vegetation. As the human population increases, there will be too many animals in too small an area. Animals also compact the soil which increasing surface runoff.
- **Overcultivation** depletes nutrients in the soil, mainly due to the overuse of chemical fertilisers and the lack of rotation of crops. When the topsoil loses **humus** (organic matter in the soil), it is more easily eroded.
- **Vegetation clearance/deforestation** for grazing land, agriculture and firewood exposes the land to wind storms and dust storms.
- **Water collection and storage** from groundwater sources such as aquifers often occurs faster than it is replaced by rainfall.
- **Salinisation:** When the water table is close to the surface, salts build up on the surface. This can then have a negative impact on crop production.
- **Mineral extraction** requires lots of water and vegetation also needs to be removed which can make the soil fragile and more prone to wind erosion.
- **Population pressures:** With increasing human populations, and consequently new agricultural techniques and increased pressure on natural resources. This can lead to depletion of soil nutrients, higher evaporation rates, increased animal grazing, and deforestation all which increase desertification.
- **Poverty** increases the percentage of people that farm on already fragile lands.
- **Policy errors** such as giving low priority to protection in low-income countries (LICs), leading to poor decisions about land management. This can lead to erosion of topsoil.

- **Climate change** leads to increasing temperatures. Higher temperatures increase evaporation and increase the risk of erosion. Can also lead to areas of food production shifting and out-migration.
- **Urban development** increases water use. It also decreases water infiltration and can create urban heat islands.

Consequences

- **Rates of soil degradation and soil erosion** increase as a result of human activity. This results in loss of soil depth and soil fertility. As a consequence of this, the level of agricultural output will decrease.
- **Feedback mechanisms:** Increased atmospheric dust due to increased wind erosion of dry soil leads to increased frequency of dust storms but also increases the **greenhouse effect** and so increases global warming. This is an example of **positive feedback**. Human activity also leads to **denudation** which is the wearing away of the earth's surface. This increases **albedo** which is the ratio between incoming radiation and the amount reflected.
- **People:** Increased frequency of food shortages and famine. This will increase the levels of **migration** which can also increase social tensions in the recipient country. There will also be an increased **dependency** on food aid and food imports which undercut local prices and as a consequence a decrease in agriculture. There will also be a loss in **traditional skills** as people are forced to settle in cities.

Management

The issues associated with settlement, transport and infrastructural development

- **Contour bunds** are constructed ridges of earth or rocks that slow down the flow of water. This allows more water to infiltrate into the ground but also prevents minerals from being washed away.
- A **Zai** is a technique where pits are dug in the earth and filled with organic matter. They trap water and nutrients. The matter is also carried by termites down into the ground which increases stability and fertility of the soils.
- **Prioritising areas for restoration.**
- **Outplanting** involves growing plants in nurseries or greenhouses before planting them in the desert. This allows them to develop a good root system so that they are able to access more water.
- **Planting trees** provides cover so decreases the rates of soil erosion and also increases biodiversity.
- **Building high tech transport systems in cities** reduce congestion and so decreases the release of **greenhouse gases**, decreases both global warming and the **urban heat island effect**.
- Taking advantage of **solar power** and **wind power** to power cities.

Issues associated with economic development

Places like **Dubai** rely heavily on **oil** for their economic development. However, oil reserves in Dubai will be **exhausted by 2025** and this is similar in many other oil-rich nations. To combat this,

many countries are actively trying to **diversify their economy** by investing in tourism, IT and banking.

Water supply is a huge issue in arid and semi-arid areas. The United Arab Emirates (UAE) now has the highest water consumption per person in the world. Many of these countries, due to large amounts of wealth, rely on **desalination** plants to provide their water. **The UAE is aiming to increase investment to US$20 billion over the next 8 years in desalination plants.**

The role of sustainable development

Sustainable development needs to be able to balance economic, social and environmental needs.

Sustainable tourism involves encouraging continual **investment** and maintenance of local jobs, **conserving** the ecosystems and landscape and protecting and **improving local customs, cultures and livelihoods**. By involving local people as much as possible, having visitor fees go towards restoring historical sites and protecting the landscapes, and by creating **national parks**, tourism will benefit the local economy and people whilst not damaging the environment.

Conservation projects such as the Eden Foundation in Niger benefit both the local people and the environment. They are planting trees and bushes which grow naturally in dry conditions and also provide food for the local people.

Sustainable mineral extraction requires **environmental assessments** of the area before mining commences to ensure that the area does not contain rare species or that mining will have a great impact on the surrounding area. Recycling water, ensuring no waste leakage and working to protect the **cryptobiotic soils** (soil that contains living organisms) are also important.

Reducing herd sizes, allowing grass to recover, planting trees, stabilising sand dunes, limiting water use and planting drought-tolerant crops are all important in creating **sustainable agriculture** in arid and semi-arid environments.