WJEC Geography A-level

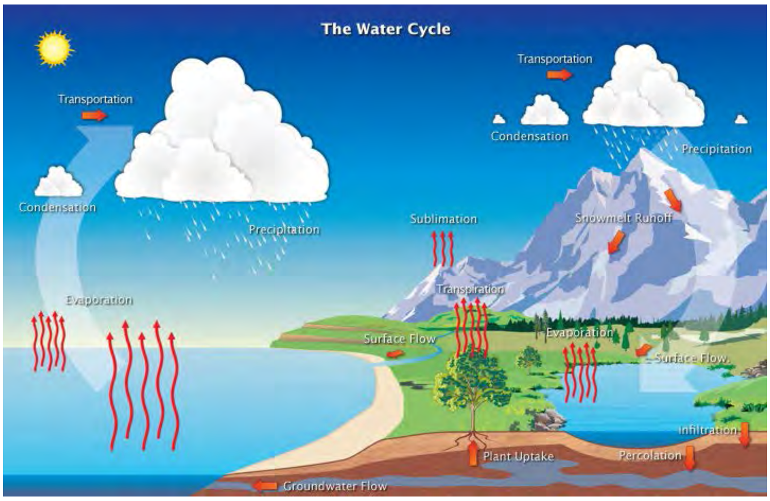
Water and Carbon Cycles

PMT Education

Written by Jeevan Singh

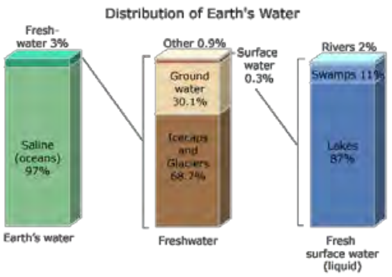
The Water Cycle

The Hydrological Cycle



- ➔ Water and the hydrological cycle are paramount in supporting life on earth. The cycle operates on a variety of spatial scales where physical processes control the circulation of water between stores on land, oceans, the cryosphere and atmosphere.
- ➔ The global hydrological cycle works as a close systems with inputs (rainwater), outputs, stores and flows. These are driven by solar energy and gravitational potential energy.

- ➔ The hydrological cycle begins with evaporation where water vapour from the ocean is lifted and condensed in the atmosphere to form clouds.



➔Moisture is then transported around the globe and returns to the surface as precipitation.

➔When reaching the ground, some water will evaporate back into the atmosphere whilst some of the water may percolate the ground to from groundwater.

➔The balance of water that remains on the surface of the earth is called runoff and emptied into lakes, rivers and streams which carry it back to the oceans for the process to start again. This is therefore a closed system.

- ➔ As seen in the graphs to the left, the percentage contribution of water stores varies, with the majority of earth's water being in saline oceans and freshwater being largely in icecaps and glaciers.
- ➔ The global water budget limits water availability for human use and water stores have different residence times; some stores, such as those storing fossil water, are non-renewable. For instance the Ogalla aquifer in the USA High Plains has stored fossil water from the previous glacial melt so cannot recharge quickly.

The Hydrological Cycle and Drainage Basins

- ➔ The drainage basin is the area of land drained by a river as shown in the image on the right. Water collected here travels downstream.
- ➔ The hydrological cycle is a system of linked processes with flows involving:
  - Interception: Precipitation that does not reach the soil as it is intercepted by vegetation and the forest floor.
  - Infiltration: Water on the ground soaking into the soils and porous rocks.
  - Throughflow: The flowing of water within the soil, moving towards the river.
  - Percolation: The movement of water through the soil or underlying porous rock, being stored as groundwater.
- ➔ Outputs occur in the form of evaporation, transpiration and channel flow. Physical factors within the drainage basin determine the importance of flows, inputs and outputs. These physical factors involve:

- Climate:
  - Temperature and precipitation patterns determine availability and vary according to latitude.
  - Seasonality determines patterns – Vancouver is wettest between October and March.
  - Summer temperatures increase evaporation rates but plant growth increases transpiration rates. Soils stores water in winter for summer use.

- Equatorial areas receive most rainfall. Mountain snow can be released as water in warmer temperatures, increasing the amount of easily accessible water.

- River Systems:

- Drainage basins collect precipitation and channels towards the coast.
- Availability depends on land use, basin size and shape and precipitation type.
- Flow increases downstream but climate creates variation in discharge and water loss.
- Climate can also produce river regimes where water is supplied through glacial and snow melt.

- Geology

- Determines underground storage according to permeability. Porous rock stores water.
- Metamorphic rocks such as granites are aquicludes, cause runoff but do not store water.
- Gravels store best if unconsolidated and bounded by impermeable rocks.

➔ Humans disrupt the drainage basin by accelerating processes such as deforestation and changing land use. By digging deep wells, there is a high risk of salinization which contaminates water sources and can cause shortages.

➔ Urbanisation increases the proportion of impermeable surfaces which prevents precipitation penetrating the ground, meaning less groundwater is stored and thus water availability declines.

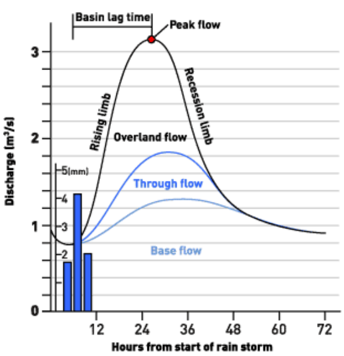
Water budgets and River Systems at Local Scales

➔ Water budgets show the annual balance between inputs, being precipitation, and outputs, through evapotranspiration, and their impact on soil water availability.

➔ Water budgets ae influence by climate types:
- Temperate: Faces mild temperatures and steady climate.
- Tropical: Can be tropical wet, tropical monsoon or tropical wet and dry seasons.
- Polar: Tundra and ice caps climates. Tundra summers are short and in ice cap seasons, temperatures are seldom above freezing.

➔ River regimes indicate the annual variation of discharge of a river and give an indication of the climate, geology and soils. As global temperatures increase, due to climate change, river discharge is likely to increase as glacier meltwater increases river input.

➔ Strom hydrograph shapes depends on human factors such as land use and urbanisation as well as physical features of the drainage basin, including:



- Shape: For rapid drainage, the shape will be circular. A long, narrow basin will mean it takes water longer to reach the river.
- Size: Smaller the basin, the less time it takes for water to drain to the river so shorter the lag time.
- Drainage Density: The higher the density, the greater the risk of flooding.
- Rock Type: Impermeable rocks encourage greater surface runoff and a more rapid increase in discharge than permeable rocks.
- Soil and Vegetation: Roots of plants take up water, reducing throughflow. Vegetation reduces the amount of discharge.
- Relief: Steeper the basin, the quicker it drains.

Deficits with the Hydrological Cycle

- Droughts are long periods of time with below average precipitation. Meteorological causes involve short-term precipitation deficit, ENSO cycles (the onset of El Niño and La Niña), anticyclones (when air does not rise so condensation and cloud formation does not occur) and changes in the ITCZ.

  - El Niño is a reverse of Walker's cells where high pressure accumulates above Australia, causing drought like conditions, whilst South America becomes a low pressure centre, at high risk of flooding and intense rainfall.
  - La Niña is an intensification of Walker's cell where Australia has a low pressure system whilst South America experiences drought like conditions due to high pressure formation.
  - In 2006, southern Australia had an extremely low rainfall season, the lowest since 1990. This caused the River Murray to dry up in places, reducing food production, social wellbeing and water supply for locals. The drought is said to be triggered by the El Niño and exacerbated by poor human management over water sources. Six million sheep died as result of the drought whilst thousands migrated away from the Murray Darling Basin.

- Human activity adds to drought risks due to the over-abstraction of surface water resources and ground water aquifers, reducing water supply.
- Additionally, deforestation reduces the soil's ability to store water, causing the land to dry out. Construction of dams on a large river, albeit producing hydro-electric power and water for farmland, can cause drought by reducing water flow downstream.

- Drought has impacts on ecosystem functioning as wetlands and the natural environment are unable to get the materials they require for adequate growth. Drought can cause a loss of wetlands and forest stress, highlighting the resilience of ecosystems.

Surpluses within the Hydrological Cycle

- Surpluses within the hydrological cycle can lead to flooding which can have disastrous impacts for people, destroying social wellbeing and economic security.
- Meteorological causes of flooding include intense storms, causing flash flooding, heavy and prolonged rainfall, a series of depressions (low pressure systems) and extreme monsoonal rainfall and snowmelt.
- Human actions such as urbanisation and deforestation increase flood risk. Urbanisation results in an increase in impermeable surfaces, allowing for surface runoff, whilst deforestation reduces the amount of water being intercepted, likewise causing an increase in surface runoff.
- As well as changing land use, mismanagement of rivers and inadequate hard engineering systems also exacerbate flood risk. The Carlisle flooding in 2005 saw two months' worth of rainfall drop in 24 hours, killing three people and leaving 2700 homes flooded. The cost of flooding was over £400 million, losing business and employment opportunities for the destroyed McVitie's Biscuit factory.
- Flood damage strains economic activity whilst ruining infrastructure and settlements. Environmental impacts involve damage to soils and ecosystems as roots are inundated.

The Role of Climate Change on the Hydrological Cycle

- Climate change effects the inputs and outputs of the hydrological cycle by altering precipitation and evaporation rates. Some areas are likely to face flooding, such as Bangladesh as it is on low lying land, whilst other regions will face prolonged drought, such as the Sahel region in Africa.
- Climate change has an impact on stores, flows, size of snow and glacier mass, reservoir, lakes, permafrost, soil moisture levels and runoff rates. The entirety of the hydrological cycle is thus at risk of change.
- Climate change's impacts are uncertain, causing concern over water supplies and efficiency of management.

Physical and Human Causes of Water Insecurity

- ➔ There is a growing mismatch between water supply and demand as demand, due to a growing population, is outstripping supply, since freshwater is a finite source.

➔ This has led to a global pattern of water stress, which involves the deterioration of water quantity and quality.

➔ Water stress is when each person has below 1700 m^3 of water whilst water scarcity is when freshwater shortages threaten food production and ecosystem wellbeing; there being below 1000 m^3 of water per person.

- ➔ Physical causes of water insecurity include climate variability and salt water encroachment at the coast where drinking water becomes contaminated as salinity increases.

- ➔ Human causes exacerbate these physical issues due to factors such as:
    - Over abstraction from rivers, lakes and groundwater: During the Green Revolution in Punjab within the 1960s, over abstraction of ground water caused salinization as wells were dug too deep to extract water, some being greater than 110 ft. deep. This reduced food production and caused water and food insecurity.
    - Water contamination from agriculture: Use of fertilisers and pesticides can wash into lakes/rivers, polluting water sources.
    - Industrial water pollution: Chemicals used in industry can contaminate water sources. Additionally there is a conflict between whether water should be use by industry, who can afford it, or used by locals for food production/living. In Kerala there was conflict between locals and Coca-Cola after allegations were made claiming the Coca-Cola company 'stole' local water sources for Coke production.

- ➔ Finite water sources face pressure from rising demands, due to increased population, improving standards of living, industrialisation and agriculture. In some locations, such increases are already threatening water security, such as in Delhi, Egypt, Jordan and Israel.

Consequence and Risks of Water Insecurity

- ➔ The price of water varies globally according to wealth. The process of cleaning water is expensive and so water price matches production costs. Additionally, in densely populated areas, water prices increase as supply cannot meet demand. In some places, such as Mexico and Kenya, a bottle of Coca-Cola is cheaper than a bottle of water, having significant impacts on water scarcity and health.
- ➔ Water supply is vital for economic development, needed for activities in industry, energy supply and agriculture. It is also important for human wellbeing such as sanitation, health and food preparation. A lack of water thus has detrimental impacts on the economy and environment.
- ➔ Water insecurity problems is likely to cause transboundary and international conflicts. One example is The Euphrates River which is predominantly controlled by Turkey, limiting supplies for downstream states such as Syria.

Managing Water Supply Sustainably

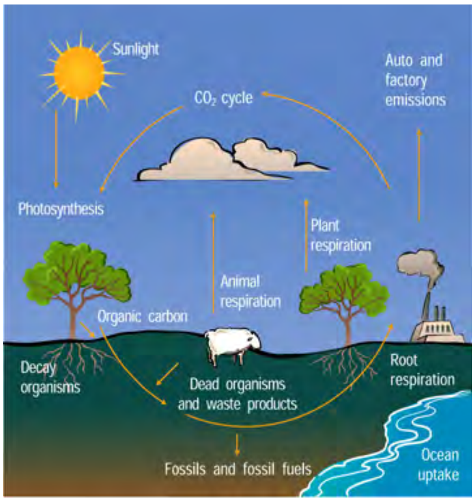
- ➔ Hard engineering schemes, including water transfers (The Australian Snowy Mountains Scheme brings water to South Australian communities) desalinisation and mega dams are effective but expensive and unsustainable.
- ➔ Water conservation, such as rainwater catchment in Singapore and Bermuda, is small scale but sustainable and cheaply done. Recycling water is environmentally friendly but some may reject the idea of using grey water (e.g. reusing water to flush).
- ➔ Integrated management can involve international treaties, such as the Helsinki Rules, but are difficult to run.

The Carbon Cycle

The Cycle

- The carbon cycle needs to be balanced to support planetary health. Physical processes control the movement of carbon between stores on land, the oceans and the atmosphere.
- Most global carbon is locked in terrestrial stores as part of the long-term geological cycle. Yet, reliance on fossil fuels has caused significant changes to carbon stores and amplified climate change.
- There is a consensus that anthropogenic climate change (caused by human activities) poses a great threat to the planet's health and the functioning of its cycles.

- The biogeochemical carbon cycle consists of carbon stores of different sizes; the terrestrial (earth), oceans and atmosphere. There are annual variations between stores of varying sizes and rates.
- Most of earth's carbon is geological, having formed from sedimentary carbonate rocks in the oceans and biologically derived carbon in shale, coal and other rocks.
- In the sea, marine animals convert some of their carbon in their diet to calcium carbonate, used to make shells. Overtime, these shells collect on the sea bed and form limestone which, when exposed to air, become weathered and release carbon dioxide back into the atmosphere.
- Geological processes also release carbon into the atmosphere through volcanic out-gassing at ocean ridges and subduction zones as well as from the chemical weathering of rocks, creating a global balance of carbon.



- The Carbon Cycle: Carbon enters the atmosphere as carbon dioxide from respiration and combustion. It is absorbed by producers via photosynthesis. Animals consume plants and the carbon compounds travel through the food chain, released via respiration. The animal dies and is eaten by decomposers which return the carbon to the atmosphere.

The Use of Biological Processes

- Phytoplankton absorb atmospheric carbon during photosynthesis in surface ocean waters. Carbonate shells move into deep ocean water through the carbonate plump (the cycling of organic matter in the ocean) and action of the thermohaline circulation which is the movement of seawater according to temperature.
- Terrestrial primary producers sequester carbon during photosynthesis which is then returned through respiration of consumer organisms.
- Biological carbon is stored as dead organic matter in soils and returned through biological decomposition, forming the final component of the carbon cycle discussed above.

The Influence of Human Activities on the Carbon Cycle

- The concentration of carbon in the atmosphere influences the natural greenhouse effect which is enhanced by fossil fuel combustion. The natural greenhouse effect is vital in regulating earth's temperature and precipitation but anthropogenic climate change has altered the balance of carbon pathways and stores, having implications on climate, ecosystems and the hydrological cycle.
- Ocean and terrestrial photosynthesis regulate the composition of gases in the atmosphere. Soil health is influence by stored carbon which is vital for ecosystem productivity. Deforestation interrupts this natural regulation by causing soil erosion.

How are the carbon and water cycles linked to the global climate system?

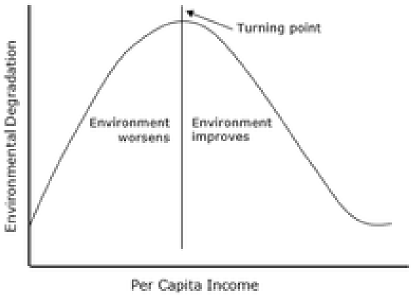
Human Activity

- As population growth has been exponential, there has been growing demand for food, fuel and other resources globally. This has led to contrasting regional trends in land use cover as deforestation, afforestation and conversion of grassland to farmland has affected terrestrial carbon stores. This effects the water cycle and soil health.
- Ocean acidification refers to the reduction in the pH of the ocean due to the uptake of carbon dioxide from the atmosphere. The ocean's role as a carbon sink is increasing due to surges in fossil fuel combustion which has caused a decline in the health of coral reefs and other marine ecosystems.

- Climate change, due to the enhanced greenhouse effect (which is largely anthropogenic), may increase the frequency of extreme weather events such as droughts and floods because shifts to the climate belts. This is likely to impact the health of forests as carbon stores.

Implications for Human Wellbeing

- Forest loss has implications on human wellbeing. Forests provide shelter, forestry, food, medicinal plants and stabilise the earth and atmosphere.
- Though deforestation is a growing problem in developing countries, there is evidence to suggest that forest stores are being more consciously protected and expanded.
- This is especially the case for more developed countries, such as the UK, where conservation is a governmental priority. Additionally, schemes such as 'debt for nature swaps', help to conserve forest stores in developing countries.
- These trends support Kuznets' curve model which concludes that, as a country's GDP and development improves, they will take more actions to conserve and protect the environment.



- Increases in temperature affect evaporation rates and the quantity of water vapour in the atmosphere. This has implications on precipitation patterns, river regimes and water stores which can affect the amount of water available for human consumption.
- Rising temperatures will mean that less water is stored in the cryosphere. Melting of glaciers will lead to flooding and a loss of freshwater. This will be detrimental for locals who rely on freshwater from glaciers, such as the Himalayan tribes. It must however be remembered that great uncertainty lies in future predictions and impacts. Threats to ocean health impact the fishing/ tourist industry and spoil coastal protection defences.

Future Risks, Players and Scales

- Future emissions, atmospheric conditions and climate warming are uncertain due to natural factors, such as the role of sinks, and human factors such as the rate of economic growth, population and energy sources.
- The role of feedback mechanisms and tipping points which can amplify change are also unknown.
- Adaptation strategies for a changed climate involve water conservation, resilient agriculture schemes, land use planning and solar radiation management. Yet these vary in effectiveness, cost and have secondary impacts, such as a reduction in food production and water availability.
- The carbon cycle could be rebalanced through mitigation techniques such as carbon taxation, renewable switching, energy efficient and CCS but these require global management and player integration.