3.3 CHANGING BLUE-GREEN-GREY WATER CYCLES

Water cycle

The circulation of the water from the earth to the atmosphere and back is called the "water cycle" or "hydrological cycle".

The recharge of water into our ecosystems and availability for human consumption involves five stages:

1) The energy of the sun leads to an evaporation of water from lakes, rivers, vegetation and oceans from where it is
2) Transported to the atmosphere in order to be
3) Condensed as tiny droplets in clouds.
4) The water in clouds then returns to the earth via precipitation
5) Either moistures soils to nourish vegetation to produce biomass, or flows downhill as run-off to either recharge groundwater or surface water storage systems such as rivers, lakes and oceans. From here it evaporates again to restart the water cycle.

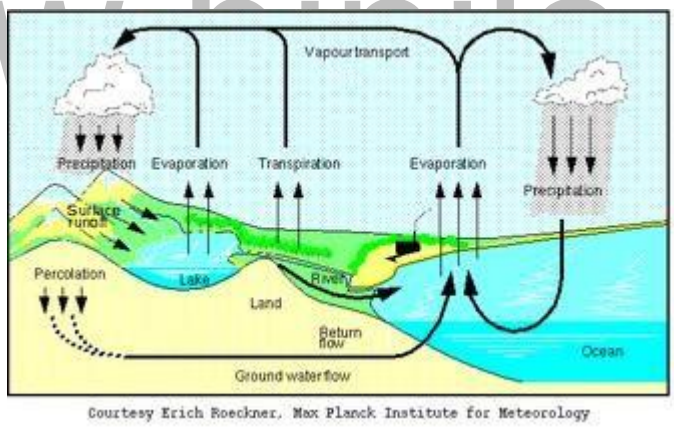

Figure 3.3.1 The hydrological cycle

[Source https://wocatpedia.net/wiki/File:The_hydrological_cycle.png]

Green water

- Precipitation is therefore the "ultimate" water source that reaches the land cover. However, the question that arises is where and how this water can be made of use for biomass production.
- The water that reaches the unsaturated zone or root-zone of plants in soils is called green water. Green water has two parts:
  - Transpiration, the productive component that produces biomass.

  - Evapo transpiration, the non-productive component that evaporates into the atmosphere.

- The subsequent water balance at any point is a measure of the water supply from incoming rainfall minus losses from outgoing evapo transpiration.
- Green water plays the most important role in biomass production. However, not all parts of the world are endowed with similar patterns of precipitation, and this unequal distribution is further being exacerbated by climate change. Green water cannot be diverted to different uses other than biomass production.

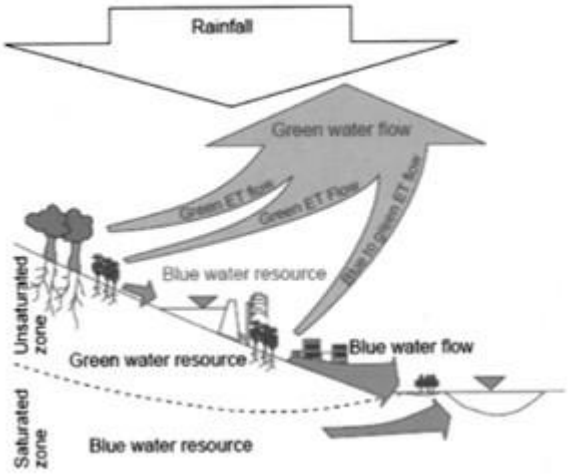

Figure 3.3.2 Conceptualisation

[Source:https://wocatpedia.net/wiki/File:Conceptualisation.png]

Blue water

- Blue water is run-off water that reaches fresh water storage systems such as rivers, lakes, wetlands and groundwater.
- Blue water can be stored and used for a specific purpose such as
  - Human consumption (drinking water)
  - Industrial consumption (including hydropower)
  - Irrigating agricultural crops to produce food and other biomass.
- In some regions of the world, such as the Middle East, blue water is sometimes the exclusive source of water due to the arid conditions in deserts.

- Blue water is often the source of water that the public associates with competition and even conflict. When used in irrigation systems, blue water has the highest productivity of all water sources.
- Blue water is found in the flows and storages of freshwater, at the surface and in groundwater aquifers. Green water, i.e. the majority of the water in the terrestrial environment and associated with vegetation, is mainly found in soil profiles, in plants and crops. Green water cycles through the hydrological cycle in the soil profile, as stem flow in plants and via the process of evapo transpiration. All green water is invisible.
- Most of the blue water is groundwater and is also invisible. Only a tiny proportion of the water in the terrestrial environment is visible, with only 1.5% is used by people.

Grey water

- Recycled water, or grey water, is a water source of growing importance in water-stressed regions such as the Middle East, as well as all across the world.
- Grey water artificially prolongs the life span of drinking water or water used in irrigation systems.
- The recycling mechanism involves several steps of filtration, microbial digestion and purification to make it fit for human consumption.

3.5 Desertification

- Desertification is defined as a process of land degradation in arid, semi-arid and sub-humid areas due to various factors including climatic variations and human activities. Or, to put it in another way, desertification results in persistent degradation of dryland and fragile ecosystems due to man-made activities and variations in climate.
- Desertification, in short, is when land that was of another type of biome turns into a desert biome because of changes of all sorts. A huge issue that many countries have is the fact that there are large pockets of land that are going through a process that is known as desertification.
- Overgrazing is the major cause of desertification worldwide. Other factors that cause desertification include urbanization, climate change, overuse of groundwater, deforestation, natural disasters, and tillage practices in agriculture that make soils more vulnerable to wind.
- Desertification affects topsoil, groundwater reserves, surface runoff, human, animal, and plant populations. Water scarcity in drylands limits the production of wood, crops, forage, and other services that ecosystems provide to our community.

- Desertification is a type of land degradation in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife.
- It is caused by a variety of factors, such as climate change and human activities. Desertification is a significant global ecological and environmental problem .

Causes of Desertification

1. Overgrazing:

Animal grazing is a huge problem for many areas that are starting to become desert biomes. If there are too many animals that are overgrazing in certain spots, it makes it difficult for the plants to grow back, which hurts the biome and makes it lose its former green glory.

2. Deforestation:

When people are looking to move into an area, or they need trees in order to make houses and do other tasks, then they are contributing to the problems related to desertification. Without the plants (especially the trees) around, the rest of the biome cannot thrive.

3. Farming Practices:

Some farmers do not know how to use the land effectively. They may essentially strip the land of everything that it has before moving on to another plot of land. By stripping the soil of its nutrients, desertification becomes more of a reality for the area that is being used for farming.

4. Excessive Use of Fertilizers and Pesticides:

The use of excessive amounts of fertilizers and pesticides to maximize their crop yields in the short term often leads to significant damages for the soil.

In the long run, this may turn from arable into arid land over time, and it will no longer be suitable for farming purposes after a few years of excessive farming since the soil has been damaged too much over time.

5. Overdrafting of groundwater:

Groundwater is the freshwater found underground and also one of the largest water sources. Over drafting is the process in which groundwater is extracted in excess of the equilibrium yield of the aquifer that is pumping or the excessive pulling up of groundwater from underground aquifers. Its depletion causes desertification.

6. Urbanization and Other Types of Land Development:

As mentioned above, development can cause people to go through and kill plant life. It can also cause issues with the soil due to chemicals and other things that may harm the ground. As areas become more urbanized, there are fewer places for plants to grow, thus causing desertification.

7. Climate Change:

Climate change plays a huge role in desertification. As the days get warmer and periods of drought become more frequent, desertification becomes more and more eminent.

Unless climate change is slowed down, huge areas of land will become desert; some of those areas may even become uninhabitable as time goes on.

8. Stripping the Land of Resources:

If an area of land has natural resources like natural gas, oil, or minerals, people will come and mine it or take it out. This usually strips the soil of nutrients, which in turn kills the plant life, and eventually leads to the process of becoming a desert biome as time goes on.

9. Natural Disasters:

There are some cases where the land gets damaged because of natural disasters, including drought. In those cases, there isn't a lot that people can do except work to try and help rehabilitate the land after it has already been damaged by nature.

10. Soil Pollution:

Soil pollution is a significant cause of desertification. Most plants are quite sensitive to their natural living conditions. When soil becomes polluted due to various human activities, the respective area of land may suffer from desertification in the long run. Higher the level of pollution more will be the degradation of soil over time.

11. Overpopulation and excessive consumption:

Since our world population is continuously growing, the demand for food and material goods is also increasing at an alarming rate. Our overall level of consumption is also increasing at a steady rate.

Thus to fulfill our demand, we have to optimize our farming processes to harvest even higher crop yields. However, this excessive optimization of farming will hurt the soil and will eventually turn into the desertification of land in the long run.

12. Mining:

Mining is another big reason for desertification. Large amounts of resources have to be extracted by industries to meet our demand for material goods. For mining, large areas of land have to be used, which causes deforestation as well as pollution of the nearby areas.

By the time most of the natural resources have been extracted, and mining practices are no more profitable, the soil gets damaged significantly, and the land becomes arid, which may not be recoverable, and desertification occurs.

Devastating Effects of Desertification

1. Farming becomes next to impossible:

If an area becomes a desert, then it's almost impossible to grow substantial crops there without special technologies. This can cost a lot of money to try and do, so many farmers will have to sell their land and leave the desert areas.

2. Decrease in Crop Yields:

A major effect of desertification is the decrease in crop yields. Once land turns from arable to arid, it is often on longer suitable for farming purposes anymore.

In turn, many farmers may lose their livelihood, since they often solely rely on farming as their single source of income. If their land becomes arid, they may no longer be able to provide sufficient crop yields to make a living out of it.

3. Hunger:

Without farms in these areas, the food that those farms produce will become much scarcer, and the people who live in those local areas will be a lot more likely to try and deal with hunger problems. Animals will also go hungry, which will cause even more of a food shortage.

4. Flooding:

Without plant life in an area, flooding is a lot more imminent. Not all deserts are dry; those that are wet could experience a lot of flooding because there is nothing to stop the water from gathering and going all over the place. Flooding can also negatively affect the water supply, which we will discuss next.

5. Poor Water Quality:

If an area becomes a desert, the water quality is going to become a lot worse than it would have been otherwise. This is because plant life plays a significant role in keeping the water clean and clear; without its presence, it becomes a lot more difficult for you to be able to do that.

6. Overpopulation:

When areas start to become desert, animals and people will go to other areas where they can actually thrive. This causes crowding and overpopulation, which will, in the long run, end up continuing the cycle of desertification that started this whole thing anyway.

7. Poverty:

All of the issues that we've talked about above (related to the problem of desertification) can lead to poverty if it is not kept in check. Without food and water, it becomes harder for people to thrive, and they take a lot of time to try and get the things that they need.

8. Biodiversity Loss:

In general, the destruction of habitats and desertification may also contribute to a loss of biodiversity. While some species may be able to adjust to the altered environmental conditions properly, many species will not be able to do so and may suffer from serious declines in population.

9. Endangerment and Extinction of Species:

The desertification results in a decline in population for which species may become endangered or even extinct. This problem is especially severe for species that are already endangered as the small number of animals or plants that remains may also die off over time, which may even lead to the extinction of species.

10. Destruction of Habitats:

Desertification often leads to a loss of habitats for many animals and plants. Desertification may alter the living conditions of the local flora and fauna that makes it impossible for animals and plants to sustain their populations.

After desertification, regions suffer from water shortages due to climate change and animals may suffer and die since water is vital for all life on our planet.

11. Migration:

The desertification implies the destruction of the livelihood of farmers. This problem becomes even worse when large areas of land that are currently used for farming will then no longer be suitable for farming due to a lack of water triggered by global warming. This results in serious migration movements.

Solutions to Desertification

1. Policy Changes Related to How People can Farm:

In countries where policy change will actually be enforced on those in the country, policy change related to how often people can farm and how much they can

farm on certain areas could be put into place to help reduce the problems that are often associated with farming and desertification.

2. Policy Changes to Other Types of Land Use:

If people are using land to get natural resources or they are developing it for people to live on, then the policies that govern them should be ones that will help the land to thrive instead of allowing them to harm the land further. The policy changes could be sweeping or they could be depending on the type of land use at hand.

3. Education:

In developing countries, education is an incredibly important tool that needs to be utilized in order to help people to understand the best way to use the land that they are farming on. By educating them on sustainable practices, more land will be saved from becoming desert.

4. Technology Advances:

Research is the key to overcome most of our environmental problems, and it applies to desertification also. In some cases, it's difficult to try and prevent desertification from happening.

In those cases, there needs to be research and application of the latest technology that pushes the limits of what we currently know about the drivers of desertification. Advancements could help us find more ways to prevent the issue from becoming an epidemic.

5. Restricting Mining Practices:

Mining often implies the destruction of large areas of land. Therefore it should be regulated by governments to keep the nature reserves intact and protect the natural habitats of many animals and plants. Thus, less land will be arid, and the desertification issue can be mitigated to a certain extent.

6. Putting Together Rehabilitation Efforts:

There are some ways that we can go back and rehabilitate the land that we've already pushed into desertification; it just takes some investment of time and money. By putting these together, we can prevent the issue from becoming even more widespread in the areas that have already been affected.

7. Reforestation:

The areas that have been subject to deforestation in the past should be considered for reforestation. Planting trees in those areas are quite important since they are natural carbon dioxide storage spaces; they slow down global warming and contribute to maintaining a natural balance.

Whereas using those areas for other purposes may turn them into arid land in the long run. Therefore, planting trees in the affected areas not only prevents desertification but also fights against additional environmental issues.

8. Sustainable Practices to Prevent Desertification From Happening:

There are plenty of sustainable practices that can be applied to those acts that may be causing desertification. By adding these to what we should be doing with land, we can ensure that we don't turn the entire world into a desert.

Desertification is a huge problem that needs to be addressed accordingly, and if we take the time to do it now, we can prevent other problems from happening with it in the future. By taking that critical look at desertification, we have the tools that we need in order to get through the processes effectively.

3.2 ECOSYSTEM CHANGES

- An ecosystem is a large community of living organisms (plants, animals and microbes) in a particular area. The living and physical components are linked together through nutrient cycles and energy flows.
- Whether just starting out or full of life, ecosystems are constantly changing. The process in which they are changing is called succession.

Succession comes in two forms:

- Primary
- Secondary.

1. Primary succession

It is "the series of community changes which occur on an entirely new habitat which has never been colonized before". These changes occur in places like area of cooled down lava, sandy areas and chiseled out rock faces.

2. Secondary succession

It is "the series of community changes which take place on a previously colonized, but disturbed or damaged habitat." These places involve areas damaged by

- Fires,
- Floods

These disturbances have not taken away all forms of life and nutrients from the area. If succession is done in a proper way, the ecosystem can become a climax community in which the ecosystem stabilizes. The process in becoming a climax community can take either a short or long time which differs from area to area. There can also be times which it is set back a few stages, like when trees are cut down. This sets the area back some, but it can still grow back and still become a climax community. The climax is stabilized by a small community of prominent species.

The web of biotic interaction that a climax community creates is so intimate that an introduction of a new species could disrupt the stabilization. If a new species were to be introduced, it could cause one species to become too dominant. However, this ecosystem would be more diverse. This loss of stabilization could easily be called a disturbance.

A disturbance is a mixture of large, infrequent and small frequent events and they can occur from the result of numerous, interconnected factors. Disturbances are categorized by type, severity, intensity, frequency, and timing. The word disturbance makes it seem like it has a negative effect on ecosystems, but the opposite is true. For example, most natural disturbances help renew ecosystems and diversify the landscapes. As stated earlier, they often lead to ecological succession. However, anthropogenic disturbances, ones related to humans, often have negative effects. For example, if humans introduce invasive species into the environment, they can hunt and prey on native species and disrupt the ecosystem's stability.

Within each type of succession is a stage. These stages include

- Pioneer
- Establishing
- Sustaining
- Producing.

Each of these is found in the types of succession new. It is and creature or plant that starts to grow or live there. It is the start of the ecosystem. This next stage is very similar to the pioneer stage.

The establishing stage is when animals or plants find things that sustain their lives and allows them to live in the area. The sustaining stage is usually in the climax succession. It is when the area can sustain life and allows life to continue in the area. The animals also do not have to leave in order to find food. The other stage is the producing stage. This is usually during the secondary succession. It happens when the population of animals is growing but many drift to other places in search for food. These places can sustain life but at a limited population. These types of succession, the stages and the disturbances that cause them all create and change and ecosystem though the years.

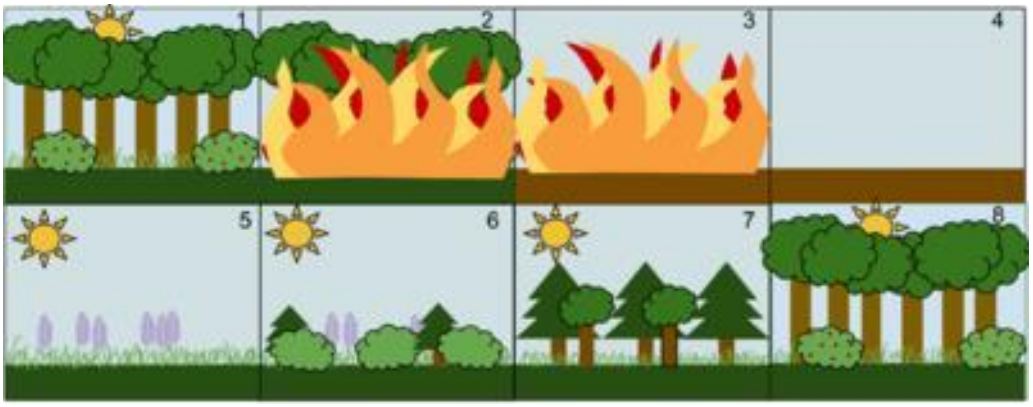

Figure 3.2.1 Secondary succession

[Source:https://en.wikipedia.org/wiki/File:Secondary_Succession.png]

Example of Secondary Succession by stages:

1. A stable deciduous forest community.
2. A disturbance, such as a fire, starts.
3. The fire destroys the vegetation.
4. The fire leaves behind empty, but not destroyed soil.
5. Grasses and other herbaceous plants grow back first.
6. Small bushes and trees begin to colonize the public area.
7. Fast-growing evergreen trees and bamboo trees develop to their fullest, while shade-tolerant trees develop in the understory.
8. The short-lived and shade-intolerant evergreen trees die as the larger deciduous trees overtop them. The ecosystem is now back to a similar state to where it began

Drivers and Ecosystems

An ecosystem consists of all of the natural elements in a specific environment and the relationships among them. Ecosystems possess not only living components, such as plants and animals, but also non-living components, like air, water, soil and rocks.

Types of ecosystems :

It include

- Forests
- Grasslands
- Tundra
- Lakes

- Wetlands
- Deltas and
- Coral reefs.

Drivers are any events or processes that change an ecosystem. Some have a direct influence on an ecosystem. Severe weather, such as a tornado, blizzard, hurricane or hail are natural events that directly impact an ecosystem. Animals such as a bear or mountain lion roam in search of new territory. This could have a direct impact on an ecosystem as the animal hunts food in its new territory, thereby reducing existing flora or fauna. The predatory animal's behavior is natural, but it can alter an ecosystem. Direct drivers may also be human influenced. The introduction of a species not normally associated with a particular ecosystem such as kudzu, silver carp or zebra mussels has a devastating impact on that ecosystem.

Wind, rain, predation and earthquakes are all examples of natural processes which impact an ecosystem. Humans also affect ecosystems by reducing habitat, over-hunting, broadcasting pesticides or fertilizers, and other influences. The line between natural and human caused effects often blurs. For example, sediment in streams and rivers can damage these tender ecosystems. But the cause may have been a post-storm mudslide or acreage stripped bare for farming. Anything that enters an ecosystem from sunlight to rain to contaminants has the potential to change it. Scientists refer to these factors as drivers.

A driver is any natural or human induced factor that directly or indirectly causes a change in an ecosystem. A direct driver unequivocally influences ecosystem processes. An indirect driver operates more diffusely, by altering one or more direct drivers. Indirect drivers of change are demographic, economic, sociopolitical, scientific and technological, and cultural and religious. Important direct drivers include climate change, plant nutrient use, and land conversion leading to habitat change, and invasive species and diseases.

Changes in Key Indirect Drivers :

- Demographic
- Economic
- Sociopolitical

- Cultural and Religious
- Science and Technology

Changes in Key Direct Drivers :

- For terrestrial ecosystems, the most important direct drivers of change in ecosystem services in the past 50 years, in the aggregate, have been land cover change (in particular, conversion to cropland) and the application of new technologies, which have contributed significantly to the increased supply of services such as food, timber, and fiber.
- Deforestation and forest degradation affect 8.5% of the world's remaining forests, nearly half of which are in South America.
- For marine ecosystems and their services, the most important direct driver of change in the past 50 years, in the aggregate, has been fishing.
- For freshwater ecosystems and their services, depending on the region, the most important direct drivers of change in the past 50 years include modification of water regimes, invasive species, and pollution, particularly high levels of nutrient loading. The introduction of non-native invasive species is one of the major causes of species extinction in freshwater systems.

- Over the past four decades, excessive nutrient loading has emerged as one of the most important direct drivers of ecosystem change in terrestrial, freshwater, and marine ecosystems. Synthetic production of nitrogen fertilizer has been the key driver for the remarkable increase in food production that has occurred during the past 50 years.
- Excessive nitrogen loading can cause algal blooms, decreased drinking water, eutrophication of freshwater ecosystems (a process whereby excessive plant growth depletes oxygen in the water), hypoxia in coastal marine ecosystems (substantial depletion of oxygen resulting in die-offs of fish and other aquatic animals), nitrous oxide emissions contributing to global climate change, and air pollution by nitrogen oxides in urban areas.
- Phosphorus application has increased threefold since 1960, with a steady increase until 1990 followed by leveling off at a level approximately equal to 1980's applications. These changes are mirrored by phosphorus accumulation in soils,

which maintains high levels of phosphorus runoff that can cause eutrophication of freshwaters and coastal waters.

- Climate change in the past century has already had a measurable impact on ecosystems.
- Biological invasions are a global phenomenon, affecting ecosystems in most biomes. Human-driven movement of organisms, deliberate or accidental, has caused a massive alteration of species ranges, overwhelming the changes that occurred after the retreat of the last Ice Age.
- Introductions of alien species can also be beneficial in terms of human population; most food is produced from introduced plants and animals.

Ecological Succession

Most ecosystem changes occur over time rather than as a result of a single, sudden event. Scientists call one such slow process ecological succession. As this process plays out, species populations fluctuate and sometimes disappear entirely. A new species entering the ecosystem such as the bear or mountain lion example is one possible trigger to launch ecological succession. Evolutionary changes that improve a particular species' adaptation is another driver. For instance, depleted food sources might change migration patterns, or one species might adapt behaviors that allow it to best its competitor species. Ecological changes to one species often influence the adaptation of others. When plants first developed flowers millions of years ago, insects adapted an attraction to nectar which had the benefit of spreading plant pollen.

Severe Storms

The sheer destructive force of storms, floods, tropical storms and tornadoes often impact ecosystems. Cataclysmic storms, such as hurricanes, bring with them high winds, storm surges and drenching rains. These factors damage ecosystems that include coral reefs, coastal marshlands and inland forests. Storm surges pour saltwater inland along coastal areas, killing freshwater vegetation and some invertebrates such as clams. Although storms are initially destructive, they may bestow some benefits to an ecosystem, such as washing away pollutants.

Other Contributors

Droughts also affect ecosystems as plant species adapted to drier climates replace those that thrive on moisture. Extended droughts increase fire risk, a natural event which can swiftly reduce a forest ecosystem. When forests redevelop, exotic foreign species may colonize there, growing faster than native ones. Naturally occurring geological hazards that affect ecosystems include volcanoes, earthquakes and tsunamis. Biological factors disease, invasive species, algae blooms also contribute to changes in ecosystems.

3.1 GLOBAL WARMING AND CHANGING ENVIRONMENT

- Global warming is a slow and steady rise in Earth's surface temperature. Temperatures today are 0.74 °C (1.33 °F) higher than 150 years ago.
- Global warming is a long-term rise in the average temperature of the Earth's climate system; an aspect of climate change shown by temperature measurements and by multiple effects of the warming.
- Increase in average air and ocean temperatures since 1900 caused mainly by emissions of greenhouse gases (GHGs) in the modern industrial economy.
- In the modern context the terms global warming and climate change are commonly used interchangeably, but climate change includes both global warming and its effects, such as changes to precipitation and impacts that differ by region.
- The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere. If a planet's atmosphere contains radiatively active gases (i.e.,greenhouse gases) they will radiate energy in all directions.
- The largest human influence has been the emission of greenhouse gases such as carbon dioxide, methane, and nitrous oxide.
- As the climate warms, it changes the nature of global rainfall, evaporation, snow, stream flow and other factors that affect water supply and quality. Specific impacts include: Warmer water temperatures affect water quality and accelerate water pollution.

Effects of global warming include :

- Rising sea levels
- Regional changes in precipitation
- More frequent extreme weather events such as heat waves, and
- Expansion of deserts.

Surface temperature increases are greatest in the Arctic, with the continuing retreat of glaciers, permafrost, and sea ice. Overall, higher temperatures

bring more rain and snowfall, but for some regions droughts and wildfires increase instead.

Climate change impacts humans by, amongst other things,

- Threatening food security from decreasing crop yields,
- The abandonment of populated areas and
- Damage to infrastructure due to rising sea levels.

Environmental impacts include,

- The extinction or relocation of ecosystems as they adapt to climate change
- With coral reefs
- Mountain ecosystems, and
- Arctic ecosystems most immediately threatened.

Because the climate system has a large "inertia" and greenhouse gases will remain in the atmosphere for a long time, climatic changes and their effects will continue to become more pronounced for many centuries even if further increases to greenhouse gases stop.

Physical drivers of climate change:

- By itself, the climate system may generate changes in global temperatures for years to decades or centuries at a time. Other changes emanate from so-called external forcings.
- These forcings are "external" to the climate system, but not necessarily external to Earth. Examples of external forcings include changes in the composition of the atmosphere (e.g., increased concentrations of greenhouse gases), solar luminosity, volcanic eruptions, and variations in Earth's orbit around the Sun.
- Attributing detected temperature changes and extreme events to man-made increases in greenhouse gases requires scientists to rule out known internal climate variability and natural external forcing.

Greenhouse gases:

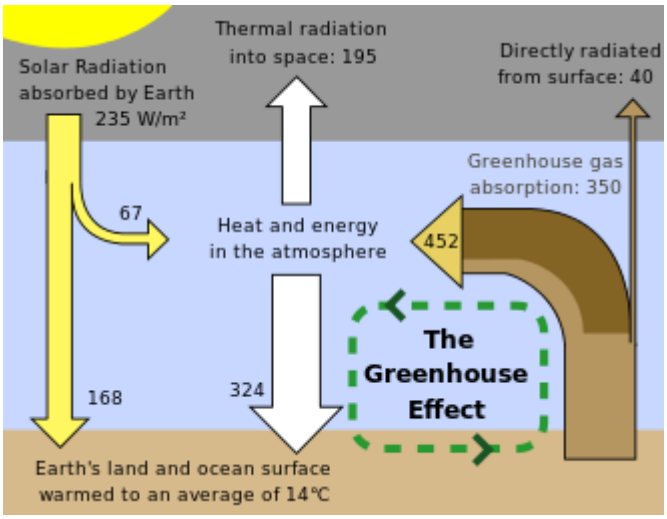

Figure 3.1.1 Greenhouse gases

[Source:https://images.app.goo.gl/Wb95qapoWmNX8nxa9]

- Greenhouse gases trap heat radiating from Earth to space. This heat, in the form of infrared radiation, gets absorbed and emitted by these gases in the planet's atmosphere thus warming the lower atmosphere and the surface.
- On Earth, an atmosphere containing naturally occurring amounts of greenhouse gases causes air temperature near the surface to be warmer by about 33 °C (59 °F) than it would be in their absence.
- Without the Earth's atmosphere, the Earth's average temperature would be well below the freezing temperature of water.

The major greenhouse gases :

- Water vapor, which causes about 36–70% of the greenhouse effect
- Carbon dioxide(CO_2), which causes 9–26%
- Methane (CH_4), which causes 4–9%
- Ozone (O_3), which causes 3–7%.

- Human activity since the Industrial Revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radioactive forcing from CO_2, methane, tropospheric ozone, CFCs, and nitrous oxide.

- Of these emissions, 65% was carbon dioxide from fossil fuel burning and industry, 11% was carbon dioxide from land use change, which is primarily due to deforestation, 16% was methane, 6.2% was nitrous oxide, and 2.0% were fluorinated gases.
- Using life-cycle assessment to estimate emissions relating to final consumption, the dominant sources of 2010 emissions were:
  - Food (26–30% of emissions)
  - Washing, heating and lighting (26%)
  - Personal transport and freight (20%)
  - Building construction (15%).

Land use change

Changing the type of vegetation in a region impacts the local temperature by changing how much sunlight gets reflected back into space and how much heat is lost by evaporation. For instance, the change from a dark forest to grassland makes the surface lighter, and causes it to reflect more sunlight. Humans change the land surface mainly to create more agricultural land.

Aerosols and soot

Solid and liquid particles known as aerosols – from volcanoes, plankton and human-made pollutants – reflect incoming sunlight, cooling the climate. From 1961 to 1990, a gradual reduction in the amount of sunlight reaching the Earth's surface was observed, a phenomenon popularly known as global dimming, typically attributed to aerosols from biofuel and fossil fuel burning. Aerosol removal by precipitation gives tropospheric aerosols an atmospheric lifetime of only about a week, while stratospheric aerosols can remain in the atmosphere for a few years. Global aerosols have been declining since 1990, removing some of the masking of global warming that aerosols had been providing.

Incoming sunlight

As the Sun is Earth's primary energy source, changes in incoming sunlight directly affect the climate system. There has been no upward trend in the amount of the Sun's energy reaching the Earth, so it cannot be responsible for the current warming.

Effects :

Physical environmental

The environmental effects of global warming are broad and far-reaching. They include the following diverse effects:

- Arctic sea ice decline, sea level rise, retreat of glaciers: global warming has led to decades of shrinking and thinning of the Arctic sea ice, making it vulnerable to atmospheric anomalies.
- Polar amplification and increased ocean warmth are undermining and threatening to unplug Antarctic glacier outlets, potentially resulting in more rapid sea level rise.
- Extreme weather, extreme events, tropical cyclones: Data analysis of extreme events from 1960 until 2010 suggests that droughts and heat waves appear simultaneously with increased frequency.
- Changes in ocean properties: increases in atmospheric CO_2 concentrations have led to an increase in dissolved CO_2 and as a consequence ocean acidity.
- Long-term effects of global warming: On the timescale of centuries to millennia, the magnitude of global warming will be determined primarily by anthropogenic CO_2 emissions. This is due to carbon dioxide's very long lifetime in the atmosphere.
- Long-term effects also include a response from the Earth's crust, due to ice melting and deglaciation, in a process called post-glacial rebound, when land masses are no longer depressed by the weight of ice. This could lead to landslides and increased seismic and volcanic activities. Tsunamis could be generated by submarine landslides caused by warmer ocean water thawing

ocean-floor permafrost or releasing gas hydrates. Sea level rise will continue over many centuries.

Biosphere:

In terrestrial ecosystems, the earlier timing of spring events, as well as pole ward and upward shifts in plant and animal ranges, have been linked with high confidence to recent warming.

- It is expected that most ecosystems will be affected by higher atmospheric CO_2 levels, combined with higher global temperatures.
- Expansion of deserts in the subtropics is probably linked to global warming.
- Ocean acidification threatens damage to coral reefs, fisheries, protected species, and other natural resources of value to society.
- The extinction of many species and reduced diversity of ecosystems.
- Land-based ecosystems are at risk of major ecological shifts, transforming composition and structure.

Impacts on humans

The effects of climate change on human systems, mostly due to warming or shifts in precipitation patterns, or both, have been detected worldwide. The future social impacts of climate change will be uneven across the world.

Food and water

- Crop production will probably be negatively affected in low latitude countries, while effects at northern latitudes may be positive or negative.
- Global warming of around 4 °C relative to late 20th century levels could pose a large risk to global and regional food security.
- Water availability will also become more limited in regions dependent on glacier water, regions with reductions in rainfall and small islands.

Health and security

- Generally impacts on public health will be more negative than positive.

- Impacts include the direct effects of extreme weather,
- Leading to injury and loss of life; and
- Indirect effects, such as under nutrition brought on by crop failures.
- Temperature rise has been connected to increased numbers of suicides
- Climate change has been linked to an increase in violent conflict by amplifying poverty and economic shocks, which are well-documented drivers of these conflicts
- A wide range of violent behaviour including fist fights, violent crimes, civil unrest, or wars.

Livelihoods, industry and infrastructure

In small islands and mega deltas, inundation as a result of sea level rise is expected to threaten vital infrastructure and human settlements. This could lead to issues of homelessness in countries with low-lying areas such as Bangladesh, as well as statelessness for populations in island nations, such as the Maldives and Tuvalu. Climate change can be an important driver of migration, both within and between countries.

Africa is one of the most vulnerable continents to climate variability and change because of multiple existing stresses and low adaptive capacity. Existing stresses include poverty, political conflicts, and ecosystem degradation. Regions may even become uninhabitable, with humidity and temperature reaching levels too high for humans to survive.

Drivers of greenhouse gas emissions

Main drivers of increases in greenhouse gas emissions

- Gross domestic product per capita and
- Population growth

CO_2 emissions are continuing to rise due to the burning of fossil fuels and land-use change.

Changes in future emission levels of greenhouse gases, have been projected that depend upon,

- Uncertain economic
- Sociological, technological, and
- Natural developments.

In most scenarios, emissions continue to rise over the century, while in a few, emissions are reduced. Fossil fuel reserves are abundant, and will not limit carbon emissions in the 21st century.

Reducing greenhouse gases

- Near- and long-term trends in the global energy system are inconsistent with limiting global warming at below 1.5 or 2 °C, relative to pre-industrial levels.
- Current pledges made as part of the Paris Agreement would lead to about 3.0 °C of warming at the end of the 21st century, relative to pre-industrial levels. In limiting warming at below 2 °C, more stringent emission reductions in the near-term would allow for less rapid reductions after 2030, and be cheaper overall. Many integrated models are unable to meet the 2 °C target if pessimistic assumptions are made about the availability of mitigation technologies.
- Co-benefits of climate change mitigation may help society and individuals more quickly. For example,
  - Cycling reduces greenhouse gas emissions while reducing the effects of a sedentary lifestyle at the same time.
  - The development and scaling-up of clean technology, such as cement that produces less CO_2.
  - It has been suggested that the most effective and comprehensive policy to reduce carbon emissions is a carbon tax or the closely related emissions trading.
  - The best approach is having fewer children, and to a lesser extent living car-free, forgoing air travel, and adopting a plant-based diet.

- A reduction in human population growth will be sufficient to mitigate global warming.

Adaptation

- Climate change adaptation is the process of adjusting to actual or expected climate and its effects. Humans can strive to moderate or avoid harm due to climate change and exploit opportunities.

Examples of adaptation are,

- Improved coastline protection,
- Better disaster management and
- The development of crops that are more resistant.

- The adaptation may be planned, either in reaction to or anticipation of global warming, or spontaneous, i.e., without government intervention.
- The public section, private sector and communities are all gaining experience with adaptation and adaptation is becoming embedded within certain planning processes. Environmental organizations and public figures have emphasized changes in the climate and the risks they entail, while promoting adaptation to changes in infrastructural needs and emissions reductions.
- Adaptation is especially important in developing main drivers of increases in greenhouse gas emissions .

Climate change:

Climate change occurs when changes in Earth's climate system result in new weather patterns that last for at least a few decades, and maybe for millions of years. The climate system comprises five interacting parts,

- The atmosphere (air)
- Hydrosphere (water)
- Cryosphere (ice and permafrost)
- Biosphere (living things)
- lithosphere (earth's crust and upper mantle).

The climate system receives nearly all of its energy from the sun, with a relatively tiny amount from earth's interior. The climate system also gives off energy to outer space. The balance of incoming and outgoing energy, and the passage of the energy through the climate system, determines Earth's energy budget. When the incoming energy is greater than the outgoing energy, earth's energy budget is positive and the climate system is warming. If more energy goes out, the energy budget is negative and earth experiences cooling.

As this energy moves through Earth's climate system, it creates Earth's weather and long-term averages of weather are called "climate". Changes in the long term average are called "climate change". Such changes can be the result of "internal variability", when natural processes inherent to the various parts of the climate system alter Earth's energy budget.

Human activities can also change earth's climate, and are presently driving climate change through global warming.

Causes Climate change:

- **Climate variability**
  - Ocean-atmosphere variability
  - Life
- **External forcing mechanisms**
  - Human influences
  - Orbital variations
  - Solar output
  - Volcanism
  - Plate tectonics

3.4 WATER SCARCITY AND WATER SHORTAGES

- Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region.
- It already affects every continent and around 2.8 billion people around the world at least one month out of every year.
- More than 1.2 billion people lack access to clean drinking water.
- Water scarcity involves water stress, water shortage or deficits, and water crisis.
- While the concept of water stress is relatively new, it is the difficulty of obtaining sources of fresh water for use during a period of time and may result in further depletion and deterioration of available water resources.
- Water shortages may be caused by climate change, such as altered weather patterns including
  - Droughts or floods
  - Increased pollution
  - Increased human demand and
  - Overuse of water.

- A water crisis is a situation where the available potable, unpolluted water within a region is less than that region's demand.
- Water scarcity is being driven by two converging phenomena:
  - Growing freshwater use
  - Depletion of usable freshwater resources.
- Water scarcity can be a result of two mechanisms:
  - Physical (absolute) water scarcity and economic water scarcity, where physical water scarcity is a result of inadequate natural water resources to supply a region's demand.
  - Economic water scarcity is a result of poor management of the sufficient available water resources.
- All causes of water scarcity are related to human interference with the water cycle. Scarcity varies over time as a result of natural hydrological variability, but varies even more so as a function of prevailing economic policy, planning and

management approaches. Scarcity can be expected to intensify with most forms of economic development, but, if correctly identified, many of its causes can be predicted, avoided or mitigated.

- Some countries have already proven that decoupling water use from economic growth is possible.

Figure 3.4.1 Water scarcity

[Source:https://images.app.goo.gl/1T9mCQz7fqHRcMie9]

Physical & economic scarcity

Water scarcity can result from two mechanisms:

- Physical (absolute) water scarcity
- Economic water scarcity

Physical water scarcity results from inadequate natural water resources to supply a region's demand, and economic water scarcity results from poor management of the sufficient available water resources.

Effects on environment

Water scarcity has many negative impacts on the environment, including lakes, rivers, wetlands and other fresh water resources. The resulting water overuse that is related to water scarcity, often located in areas of irrigation agriculture, harms the environment in several ways including increased salinity, nutrient pollution, and the loss of floodplains and wetlands.

Through the last hundred years, more than half of the Earth's wetlands have been destroyed and have disappeared. These wetlands are important not only because

they are the habitats of numerous inhabitants such as mammals, birds, fish, amphibians, and invertebrates, but they support the growing of rice and other food crops as well as provide water filtration and protection from storms and flooding.

Causes and contributing factors:

Climate change

Aquifer drawdown or over drafting and the pumping of fossil water increases the total amount of water within the hydrosphere subject to transpiration and evaporation processes, thereby causing accretion in water vapour and cloud cover, the primary absorbers of infrared radiation in the earth's atmosphere.

Depletion of freshwater resources

Apart from the conventional surface water sources of freshwater such as rivers and lakes, other resources of freshwater such as groundwater and glaciers have become more developed sources of freshwater, becoming the main source of clean water. Groundwater is water that has pooled below the surface of the Earth and can provide a usable quantity of water through springs or wells. These areas where groundwater is collected are also known as aquifers. Glaciers provide freshwater in the form meltwater, or freshwater melted from snow or ice, that supply streams or springs as temperatures rise. More and more of these sources are being drawn upon as conventional sources' usability decreases due to factors such as pollution or disappearance due to climate changes. Human population growth is a significant contributing factor in the increasing use of these types of water resources.

Groundwater

Until recent history, groundwater was not a highly utilized resource. Changes in knowledge, technology and funding have allowed for focused development into abstracting water from groundwater resources away from surface water resources. These changes allowed for progress in society such as the "agricultural groundwater revolution", expanding the irrigation sector allowing for increased food production and

development in rural areas. Groundwater supplies nearly half of all drinking water in the world.

Glaciers

Glaciers are noted as a vital water source due to their contribution to stream flow. Rising global temperatures have noticeable effects on the rate at which glaciers melt, causing glaciers in general to shrink worldwide. Although the melt water from these glaciers are increasing the total water supply for the present, the disappearance of glaciers in the long term will diminish available water resources. Increased melt water due to rising global temperatures can also have negative effects such as flooding of lakes and dams and catastrophic results.

Expansion of agricultural and industrial users

Scarcity as a result of consumption is caused primarily by the extensive use of water in agriculture/livestock breeding and industry. People in developed countries generally use about 10 times more water daily than those in developing countries. A large part of this is indirect use in water-intensive agricultural and industrial production processes of consumer goods, such as fruit, oilseed crops and cotton. Because many of these production chains have been globalized, a lot of water in developing countries is being used and polluted in order to produce goods destined for consumption in developed countries.

Business activity ranging from industrialization to services such as tourism and entertainment continues to expand rapidly. This expansion requires increased water services including both supply and sanitation, which can lead to more pressure on water resources and natural ecosystem. The approximate 50% growth in world energy use by 2040 will also increase the need for efficient water use, and may shift some irrigation water sources towards industrial use, as thermal power generation uses water for steam generation and cooling.

Population growth

Around fifty years ago, the common perception was that water was an infinite resource. At that time, there were fewer than half the current number of people on the planet. People were not as wealthy as today, consumed fewer calories and ate

less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. This is because there are now seven billion people on the planet, their consumption of water-thirsty meat is rising, and there is increasing competition for water from industry, urbanisation bio fuel crops, and water reliant food items. In the future, even more water will be needed to produce food because the Earth's population is forecast to rise to 9 billion by 2050.

In 2000, the world population was 6.2 billion. The UN estimates that by 2050 there will be an additional 3.5 billion people with most of the growth in developing countries that already suffer water stress. Thus, water demand will increase unless there are corresponding increases in water conservation and recycling of this vital resource. In building on the data presented here by the UN, the World Bank goes on to explain that access to water for producing food will be one of the main challenges in the decades to come. Access to water will need to be balanced with the importance of managing water itself in a sustainable way while taking into account the impact of climate change, and other environmental and social variables.

Rapid urbanization

The trend towards urbanization is accelerating. Small private wells and septic tanks that work well in low-density communities are not feasible within high-density urban areas. Urbanization requires significant investment in water infrastructure in order to deliver water to individuals and to process the concentrations of wastewater – both from individuals and from business. These polluted and contaminated waters must be treated or they pose unacceptable public health risks. In 60% of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished. Even if some water remains available, it costs increasingly more to capture it.

Impacts of water scarcity:

There are several principal manifestations of the water crisis.

- Food security in the Middle East and North Africa Region
- Inadequate access to safe drinking water for about 885 million people

- Inadequate access to sanitation for 2.5 billion people, which often leads to water pollution.
- Groundwater over drafting leading to diminished agricultural yields
- Overuse and pollution of water resources harming biodiversity
- Regional conflicts over scarce water resources sometimes resulting in warfare .