

Frequently Asked Questions

FAQ

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These Frequently Asked Questions have been extracted from the chapters of the underlying report and are compiled here. When referencing specific FAQs, please reference the corresponding chapter in the report from where the FAQ originated (e.g., FAQ 3.1 is part of Chapter 3).

FAQ 8.1 | How Does Land Use Change Alter the Water Cycle?

The ways in which humans use and change land cover, for example by converting fields to urban areas or clearing forests, can affect every aspect of the water cycle. Land-use changes can alter precipitation patterns and how water is absorbed into the ground, flows into streams and rivers, or floods the land surface, as well as how moisture evaporates back into the air. Changes in any of these aspects of the interconnected water cycle can affect the entire cycle and the availability of freshwater resources.

Land use describes the combination of activities and ground cover defining each area of the Earth's continental surface. Altering land use can modify the exchange of water between the atmosphere, soil and subsurface (FAQ 8.1, Figure 1).

For instance, changes in land cover can affect the ability of soils to soak up surface water (infiltration). When soil loses its capacity to soak up water, precipitation that would normally infiltrate and contribute to groundwater reserves will instead overflow, increasing surface water (runoff) and the likelihood of flooding. For example, changing from vegetation to urban cover can cause water to flow rapidly over buildings, roads and driveways and into drains rather than soaking into the ground. Deforestation over wide areas can also directly reduce soil moisture, evaporation and rainfall locally but can also cause regional temperature changes that affect rainfall patterns.

Extracting water from the ground and river systems for agriculture, industry and drinking water depletes groundwater and can increase surface evaporation because water that was previously in the ground is now in direct contact with the atmosphere, being available for evaporation.

Changing land use can also alter how wet the soil is, influencing how quickly the ground heats up and cools down and the local water cycle. Drier soils evaporate less water into the air but heat up more in the day. This can lead to warmer, more buoyant plumes of air that can promote cloud development and precipitation if there is enough moisture in the air.

Changes in land use can also modify the amount of tiny aerosol particles in the air. For instance, industrial and domestic activities can contribute to aerosol emissions, as do natural environments such as forests or salt lakes. Aerosols cool down global temperature by blocking out sunlight but can also affect the formation of clouds and therefore the occurrence of precipitation (see FAQ 7.2).

Vegetation plays an important role in soaking up soil moisture and evaporating water into the air (*transpiration*) through tiny holes (*stomata*) that allow the plants to take in carbon dioxide. Some plants are better at retaining water than others, so changes in vegetation can affect how much water infiltrates into the ground, flows into streams and rivers, or is evaporated.

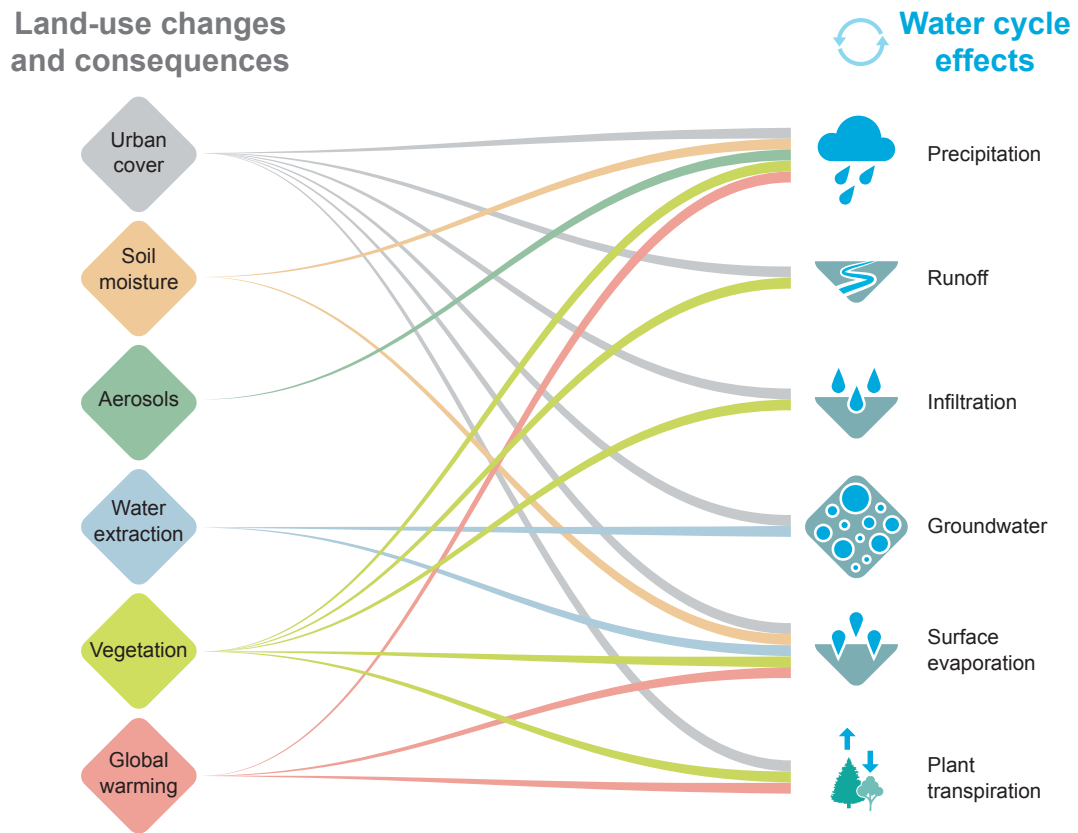
More globally, land-use change is currently responsible for about 15% of the emissions of carbon dioxide from human activities, leading to global warming, which in turn affects precipitation, evaporation, and plant transpiration. In addition, higher atmospheric concentrations of carbon dioxide due to human activities can make plants more efficient at retaining water because the stomata do not need to open so widely. Improved land and water management (e.g., reforestation, sustainable irrigation) can also contribute to reducing climate change and adapting to some of its adverse consequences.

In summary, there is abundant evidence that changes in land use and land cover alter the water cycle globally, regionally and locally, by changing precipitation, evaporation, flooding, groundwater, and the availability of freshwater for a variety of uses. Since all the components of the water cycle are connected (and linked to the carbon cycle), changes in land use trickle down to many other components of the water cycle and climate system.

FAQ 8.1 (continued)

FAQ 8.1: How do land use changes affect the water cycle?

Altering land use affects the water cycle in many ways, with subsequent consequences for the whole cycle.



FAQ 8.1, Figure 1 | Land-use changes and their consequences on the water cycle. As all the components of the water cycle are tightly connected, changes in one aspect of the cycle affects almost all the cycle.

FAQ

FAQ 8.2 | Will Floods Become More Severe or More Frequent as a Result of Climate Change?

A warmer climate increases the amount and intensity of rainfall during wet events, and this is expected to amplify the severity of flooding. However, the link between rainfall and flooding is complex, so while the most severe flooding events are expected to worsen, floods could become rarer in some regions.

Floods are a natural and important part of the water cycle but they can also threaten lives and safety, disrupt human activities, and damage infrastructure. Most inland floods occur when rivers overtop their banks (*fluvial* flooding) or when intense rainfall causes water to build up and overflow locally (*pluvial* flooding). Flooding is also caused by coastal inundation by the sea, rapid seasonal melting of snow, and the accumulation of debris, such as vegetation or ice, that stops water from draining away.

Climate change is already altering the location, frequency and severity of flooding. Close to the coasts, rising sea levels increasingly cause more frequent and severe coastal flooding, and the severity of these floods is exacerbated when combined with heavy rainfall. The heavy and sustained rainfall events responsible for most inland flooding are becoming more intense in many areas as the climate warms because air near Earth's surface can carry around 7% more water in its gas phase (vapour) for each 1°C of warming. This extra moisture is drawn into weather systems, fueling heavier rainfall (FAQ 8.2, Figure 1).

A warming climate also affects wind patterns, how storms form and evolve, and the pathway those storms usually travel. Warming also increases condensation rates, which in turn releases extra heat that can energize storm systems and further intensify rainfall. On the other hand, this energy release can also inhibit the uplift required for cloud development, while increases in particle pollution can delay rainfall but invigorate storms. These changes mean that the character of precipitation events (how often, how long lasting and how heavy they are) will continue to change as the climate warms.

In addition to climate change, the location, frequency and timing of the heaviest rainfall events and worst flooding depend on natural fluctuations in wind patterns that make some regions unusually wet or dry for months, years, or even decades. These natural variations make it difficult to determine whether heavy rainfall events are changing locally as a result of global warming. However, when natural weather patterns bring heavy and prolonged rainfall in a warmer climate, the intensity is increased by the larger amount of moisture in the air.

An increased intensity and frequency of record-breaking daily rainfall has been detected for much of the land surface where good observational records exist, and this can only be explained by human-caused increases in atmospheric greenhouse gas concentrations. Heavy rainfall is also projected to become more intense in the future for most places. So, where unusually wet weather events or seasons occur, the rainfall amounts are expected to be greater in the future, contributing to more severe flooding.

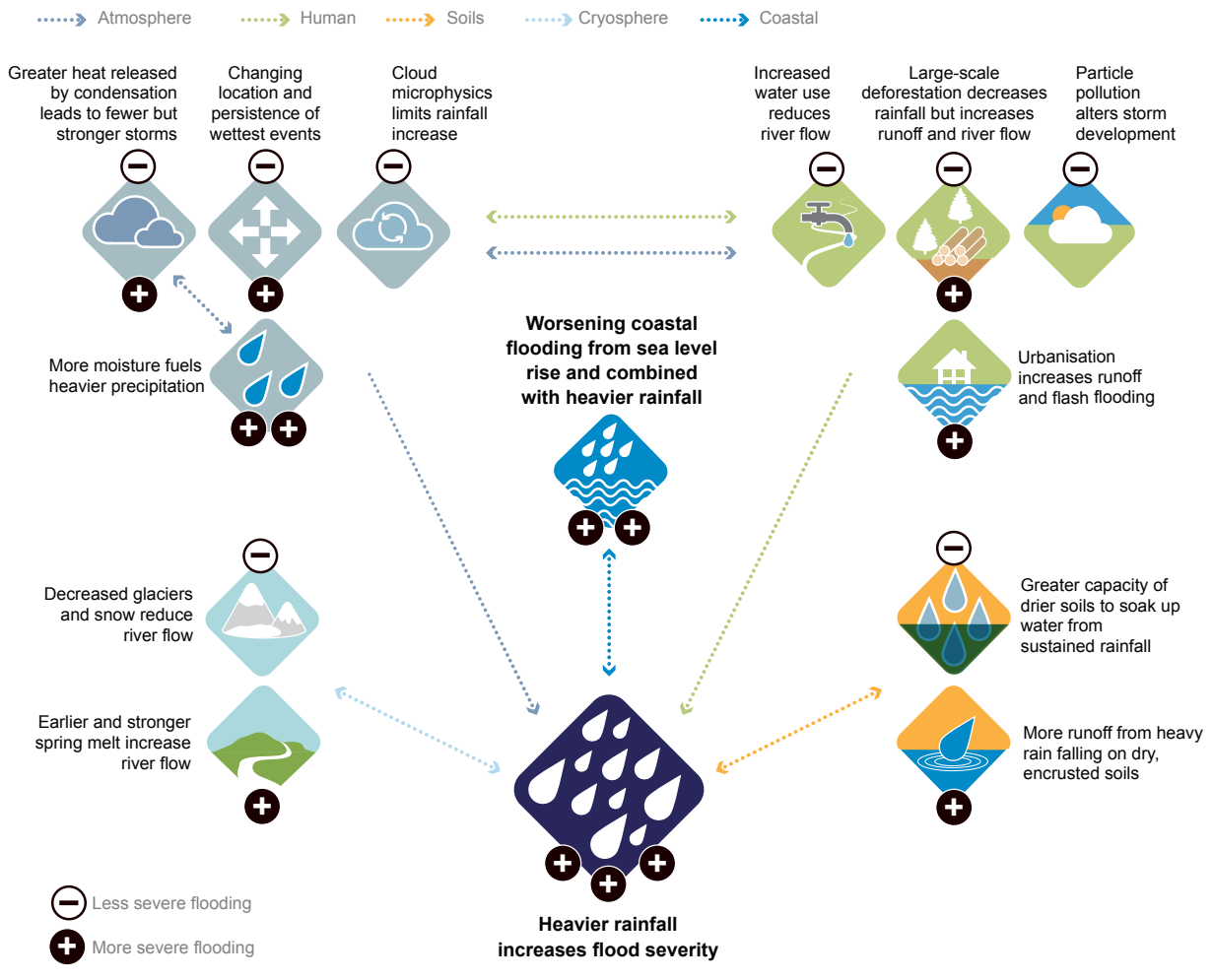
However, heavier rainfall does not always lead to greater flooding. This is because flooding also depends upon the type of river basin, the surface landscape, the extent and duration of the rainfall, and how wet the ground is before the rainfall event (FAQ 8.2, Figure 1). Some regions will experience a drying in the soil as the climate warms, particularly in subtropical climates, which could make floods from a rainfall event less probable because the ground can potentially soak up more of the rain. On the other hand, less frequent but more intense downpours can lead to dry, hard ground that is less able to soak up heavy rainfall when it does occur, resulting in more runoff into lakes, rivers and hollows. Earlier spring snowmelt combined with more precipitation falling as rain rather than snow can trigger flood events in cold regions. Reduced winter snow cover can, in contrast, decrease the chance of flooding arising from the combination of rainfall and rapid snowmelt. Rapid melting of glaciers and snow in a warming climate is already increasing river flow in some regions, but as the volumes of ice diminish, flows will peak and then decline in the future. Flooding is also affected by changes in the management of the land and river systems. For example, clearing forests for agriculture or building cities can make rainwater flow more rapidly into rivers or low-lying areas. On the other hand, increased extraction of water from rivers can reduce water levels and the likelihood of flooding.

FAQ 8.2 (continued)

A mix of both increases and decreases in flooding have been observed in some regions and these changes have been attributed to multiple causes, including changes in snowmelt, soil moisture and rainfall. Although we know that a warming climate will intensify rainfall events, local and regional trends are expected to vary in both direction and magnitude as global warming results in multiple, and sometimes counteracting, influences. However, even accounting for the many factors that generate flooding, when weather patterns cause flood events in a warmer future, these floods will be more severe.

FAQ 8.2: Causes of more severe floods from climate change

Flooding presents a hazard but the link between rainfall and flooding is not simple. While the largest flooding events can be expected to worsen, flood occurrence may decrease in some regions.



FAQ 8.2, Figure 1 | Schematic illustrating factors important in determining changes in heavy precipitation and flooding.

FAQ

FAQ 8.3 | What Causes Droughts, and Will Climate Change Make Them Worse?

Droughts usually begin as a deficit of precipitation, but then propagate to other parts of the water cycle (soils, rivers, snowlice and water reservoirs). They are also influenced by factors like temperature, vegetation and human land and water management. In a warmer world, evaporation increases, which can make even wet regions more susceptible to drought.

A drought is broadly defined as drier than normal conditions; that is, a moisture deficit relative to the average water availability at a given location and season. Since they are locally defined, a drought in a wet place will not have the same amount of water deficit as a drought in a dry region. Droughts are divided into different categories based on where in the water cycle the moisture deficit occurs: meteorological drought (precipitation), hydrological drought (runoff, streamflow, and reservoir storage), and agricultural or ecological drought (plant stress from a combination of evaporation and low soil moisture). Special categories of drought also exist. For example, a snow drought occurs when winter snowpack levels are below average, which can cause abnormally low streamflow in subsequent seasons. And while many drought events develop slowly over months or years, some events, called flash droughts, can intensify over the course of days or weeks. One such event occurred in 2012 in the Midwestern region of North America and had a severe impact on agricultural production, with losses exceeding \$30 billion US dollars. Droughts typically only become a concern when they adversely affect people (reducing water available for municipal, industrial, agricultural, or navigational needs) and/or ecosystems (adverse effects on natural flora and fauna). When a drought lasts for a very long time (more than two decades) it is sometimes called a megadrought.

Most droughts begin when precipitation is below normal for an extended period of time (meteorological drought). This typically occurs when high pressure in the atmosphere sets up over a region, reducing cloud formation and precipitation over that area and deflecting away storms. The lack of rainfall then propagates across the water cycle to create agricultural drought in soils and hydrological drought in waterways. Other processes act to amplify or alleviate droughts. For example, if temperatures are abnormally high, evaporation increases, drying out soils and streams and stressing plants beyond what would have occurred from the lack of precipitation alone. Vegetation can play a critical role because it modulates many important hydrologic processes (soil water, evapotranspiration, runoff). Human activities can also determine how severe a drought is. For example, irrigating croplands can reduce the socio-economic impact of a drought; at the same time, depletion of groundwater in aquifers can make a drought worse.

The effect of climate change on drought varies across regions. In the subtropical regions like the Mediterranean, southern Africa, south-western Australia and south-western South America, as well as tropical Central America, western Africa and the Amazon basin, precipitation is expected to decline as the world warms, increasing the possibility that drought will occur throughout the year (FAQ 8.3, Figure 1). Warming will decrease snowpack, amplifying drought in regions where snowmelt is an important water resource (such as in south-western South America). Higher temperatures lead to increased evaporation, resulting in soil drying, increased plant stress, and impacts on agriculture, even in regions where large changes in precipitation are not expected (such as central and northern Europe). If emissions of greenhouse gases are not curtailed, about a third of global land areas are projected to suffer from at least moderate drought by 2100. On the other hand, some areas and seasons (such as high-latitude regions in North America and Asia, and the South Asian monsoon region) may experience increases in precipitation as a result of climate change, which will decrease the likelihood of droughts. FAQ 8.3, Figure 1 highlights the regions where climate change is expected to increase the severity of droughts.

FAQ 8.3 (continued)

FAQ 8.3: Climate change and drought

In some regions, **drought** is expected to increase under future warming.



FAQ 8.3, Figure 1 | Schematic map highlighting in brown the regions where droughts are expected to become worse as a result of climate change. This pattern is similar regardless of the emissions scenario; however, the magnitude of change increases under higher emissions.