Evidence #1: Land use changes have generated large pressures on freshwater resources. These changes are affecting both water quality and availability.

Farming, mining, and forestry require large amounts of water. Almost half of our land is used for farming. As populations continue to grow, there will be less water available to use for crops. In countries where climate change has affected weather patterns, there will be even less available water. Such countries include the Philippines, Pakistan, Vietnam, and Australia.

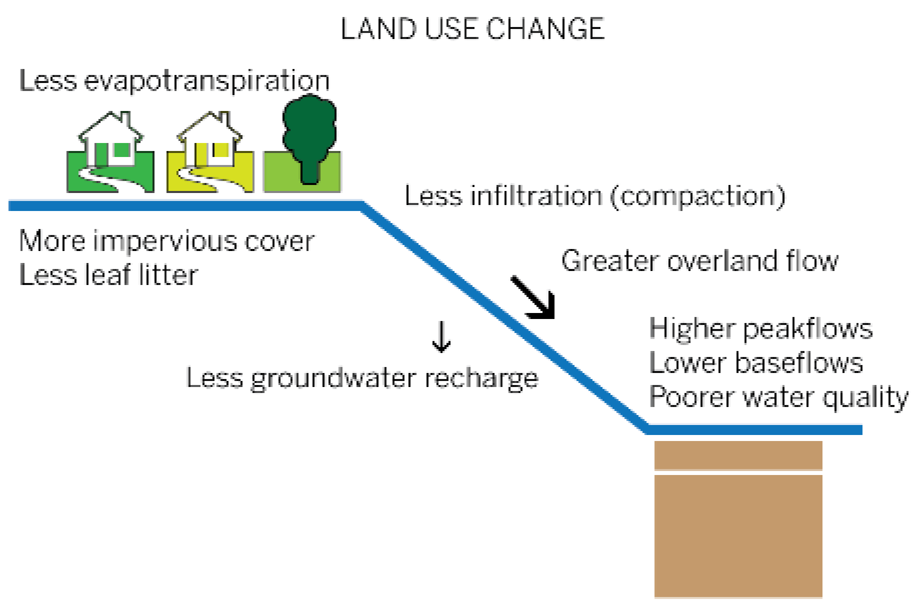

Figure 1: Changes in the movement of water when land use changes. Credit: Wright Seneres

As land use is changed, the water cycle is altered at local and regional levels. Figure 1 shows that increasing the amounts of solid surfaces leads to greater runoff. Houses, roads, and other structures block some water from going into the ground. When this happens, more water runs off into local bodies of water. The water that runs into the local bodies of water includes anything that it can carry along the way. This can decrease water quality.

Evidence #2: The world's population is increasing. This stresses the supply of freshwater.

Each person requires at least 50 liters/day of freshwater for drinking, eating, and cleaning. There are more than 7.5 billion people in the world. By the year 2050, there will be 9.5 billion people. In the next 30 years, the amount of people living in cities will also increase. This will stress the supply of freshwater.

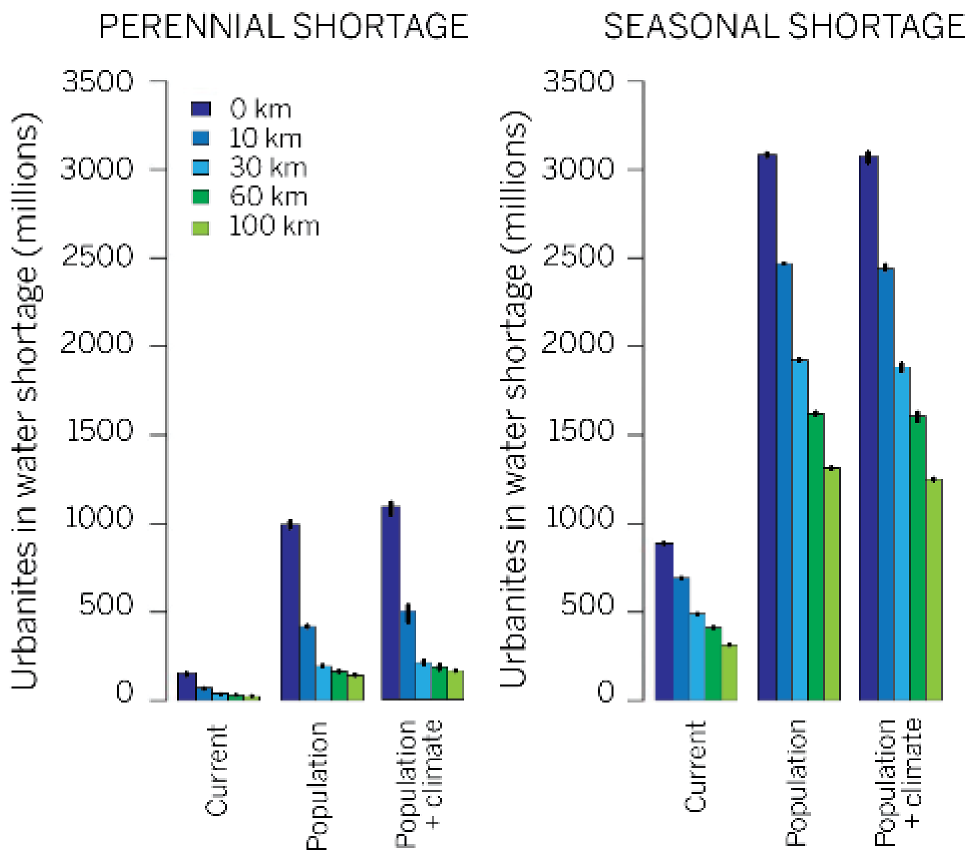

Figure 1. Urban populations affected by freshwater shortages. Credit: Wright Seneres from United Nations data.

Figure 1 above shows water shortages in cities. On the left are yearly amounts and on the right are seasonal amounts. Water shortages occur when an urban area has 100 liters (or less) of water per person per day. The bars show different distances from urban areas. Shortage numbers are represented in three categories: (a) current population, (b) 2050 population, and (c) 2050 population growth plus climate.

Evidence #3: Groundwater provides freshwater to many people around the world. In many places, people are using groundwater faster than it is replaced by precipitation.

Groundwater exists below the surface. It can be replaced through precipitation. Some groundwater is called "fossil water" because it is located deep below the surface. Once humans use groundwater, it takes thousands of years to be replaced.

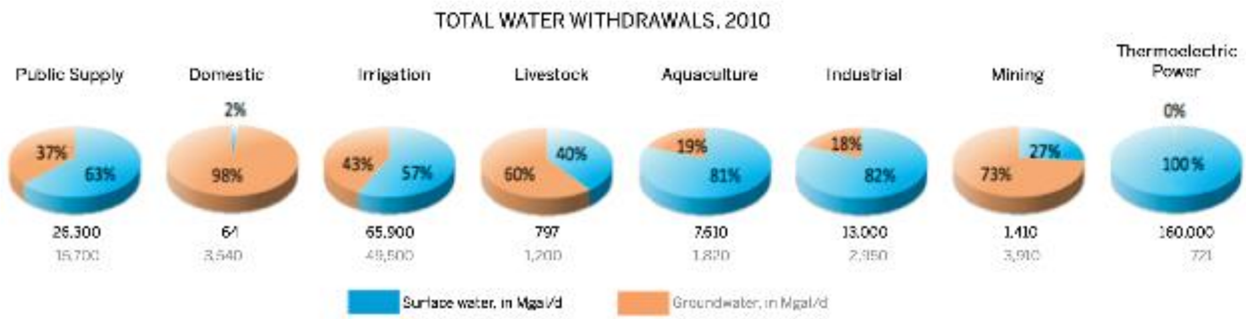

Figure 1. Water used for different human activities. Credit: Wright Seneres based on USGS data.

Figure 1 above shows how humans use both surface water (shown in blue) and groundwater (shown in yellow). About half of the freshwater humans use comes from groundwater.

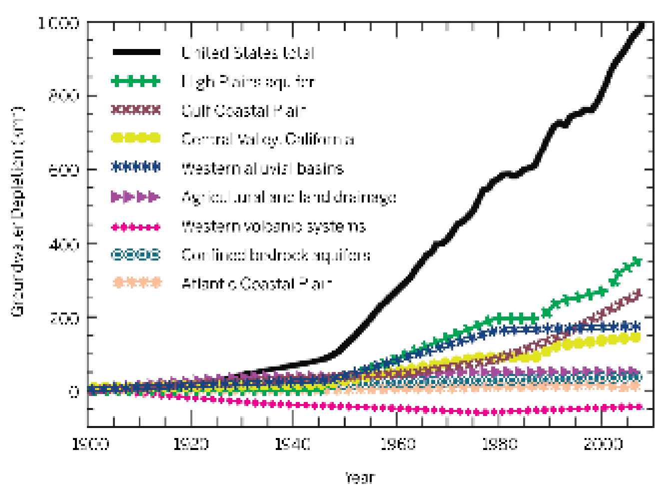

Figure 2. Groundwater depletion in the United States. Credit: Wright Seneres based on USGS data.

In many areas, groundwater is removed faster than it is replaced. This is called depletion. The black line in Figure 2 above shows how much water has been depleted since the year 1900. This depletion of groundwater can lead to sinking land areas (subsidence). It can also cause saltwater to move into groundwater in coastal areas.

Evidence #4: Water reclamation and desalination costs are expensive. These costs vary depending on location.

Dirty water, also called wastewater, can be converted for future use. This process is called reclamation. Sometimes, dirty water can be converted into drinking water. Drinking water is also called potable water. Reclamation costs a lot and uses large amounts of energy. The cost of reclamation varies by location. It depends on the level of treatment and distance the water needs to be transported for use.

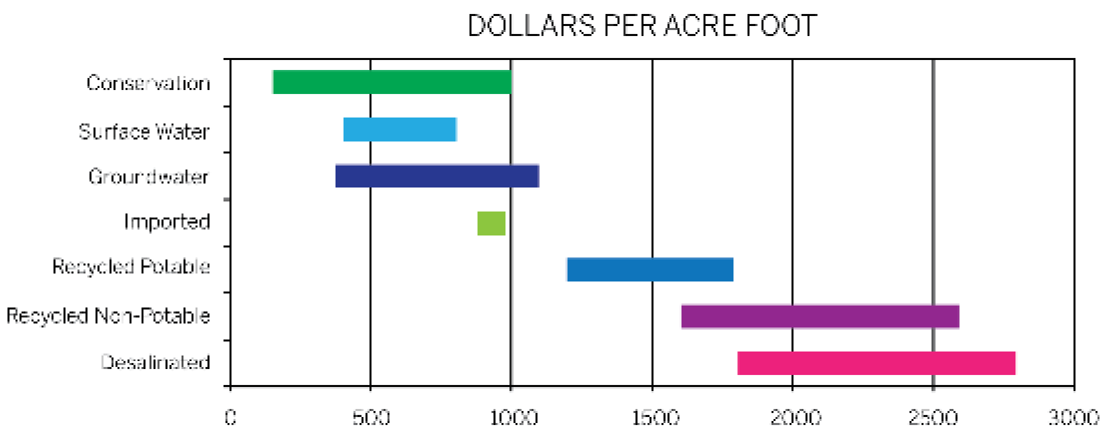

Figure 1. Water costs in 2010 for San Diego County, California. Credit: Wright Seneres based on NRC (2012).

Figure 1 shows how much certain types of water cost in the year 2010. The dark blue and purple bars show reclamation costs for drinking water and wastewater. The pink bar shows desalination costs. Desalination is the removal of salt from saltwater. These costs are in dollars per acre-foot (a unit of volume, where 1 acre-foot is just over 320,000 gallons or 1.2 million liters).

Evidence #5: Advances in engineering have led to better access to quality drinking water. At the same time life expectancy and quality of life have improved.

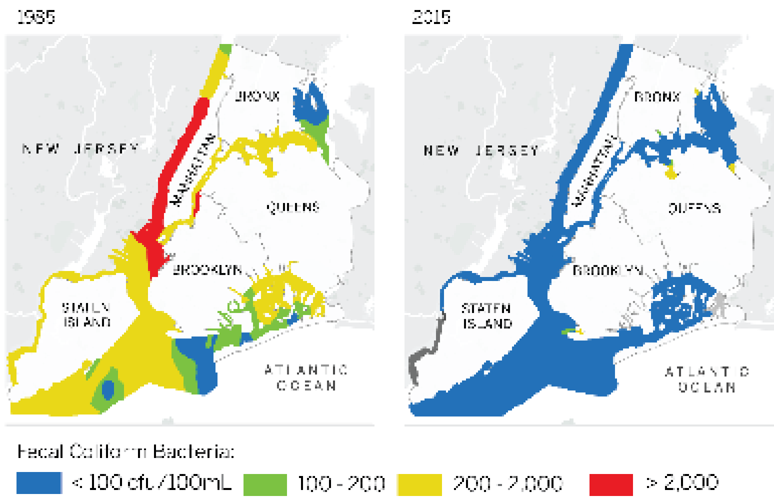

Figure 1. Changes in fecal coliform counts over time. Credit: Wright Seneres.

Figure 1 above shows data from New York City. It shows how water quality has improved since the year 1985. Fecal coliforms are a bacteria that make the water quality worse. The figure shows how fecal coliforms have decreased. New York City spent about $10 billion on improving the quality of water.

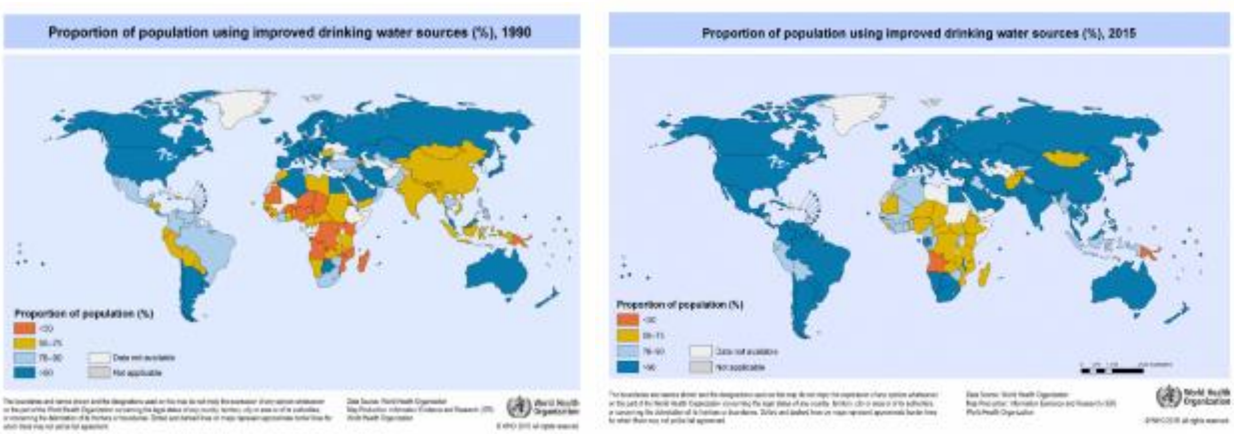

Figure 2. Proportion of population using improved drinking water sources in 1990 (left) and 2015 (right) ()

The quality of water has increased around the world. Figure 2 shows how the proportions of the world’s population have more and better access to drinking water. Dark blue shaded areas show where 90% of the people have access to improved drinking water.

Evidence #6: Glaciers are a source of freshwater in many parts of the world. Glacial ice mass is decreasing worldwide.

The Tibetan Plateau in Asia is the highest plateau in the world. It supplies water for millions of people. The snowpack that accumulates in the winter melts during summer months. The runoff from this melting feeds river systems that are used for agriculture.

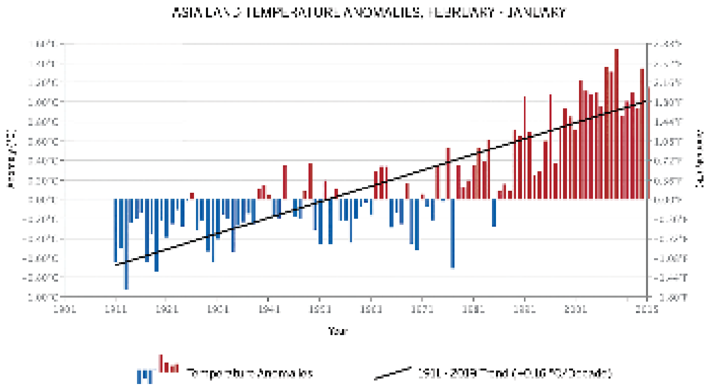

Figure 1. Trend in average temperatures across Asia. Credit: Wright Seneres based on NOAA data.

Figure 1 above shows that temperatures in Asia have increased. The rate of increase is about 0.35°C per decade. Higher temperatures have reduced the amount of snow in the Tibetan Plateau. Glacial ice mass on the Tibetan Plateau has decreased 6% since the 1970s. Almost all of the glaciers in this area are losing more ice mass than they are gaining, resulting in an overall loss of ice mass. In the northern part of the Tibetan Plateau lakes have dried up. Deserts now cover about 17% of the plateau. In the southern part of the plateau, there has been glacial melt, frequent flooding, and landslides. Figure 2 shows that increased temperature has led to a decrease in glacial ice worldwide.

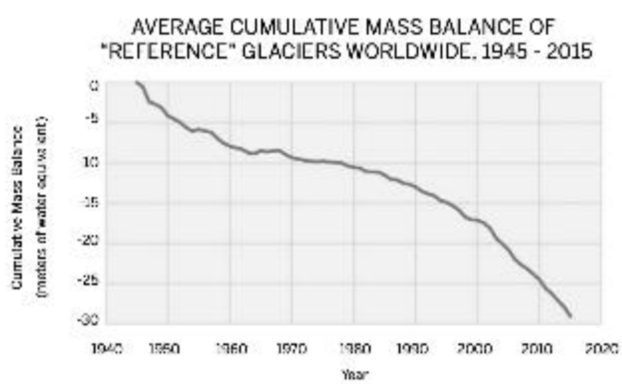

Figure 2. Average mass of glaciers worldwide. Credit: Wright Seneres based on EPA data.

Evidence #7: Microclimates are climates of very small areas that usually differ from the surrounding areas. Scientists are developing high-resolution models to accurately predict microclimate trends in freshwater availability.

Microclimates are influenced by trees, mountains, or closeness to large bodies of water.
For example, the figure below shows the northern part of the Big Island of Hawaii. A mountain range extends from Mt. Kohala to Mauna Kea. Mountains can influence how much rain falls in an area. The range of mountains from Mt. Kohala to Mauna Kea creates a barrier that prevents rain from falling on the southern end. This is called a rain shadow. Locations in rain shadows may have less access to freshwater. This is called the leeward side. The other side is called the windward side and generally receives ample rainfall.

Figure 1. Rain shadow on Hawaii's Big Island. Credit: Wright Seneres.

Many climate change predictions focus on large scales. These simulations can be regional, national, or global. However, predicted changes may be different between the large scale and the local scale of microclimates. Scientists have recently developed high-resolution climate models that produce rainfall simulations in microclimates that are accurate based on past observations. Scientists expect predictions about freshwater availability from these high-resolution models to be more accurate than global models. Some predictions show decreasing freshwater availability.

Evidence #8: In the contiguous US, average temperatures and precipitation have increased since 1901. From 2000-2015, the US was abnormally dry with some parts of the country in moderate to severe drought.

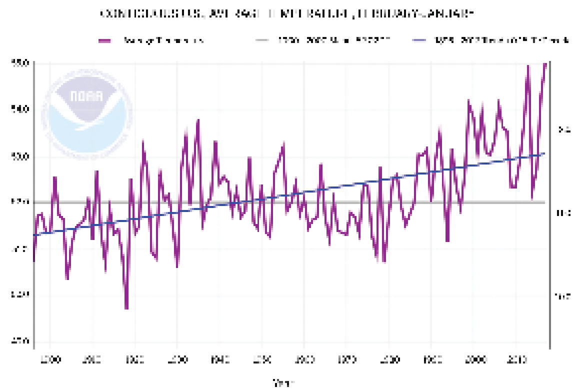

Figure 1. Average annual temperatures 1901-2017 for the contiguous United States. Credit: Wright Seneres based on NOAA data.

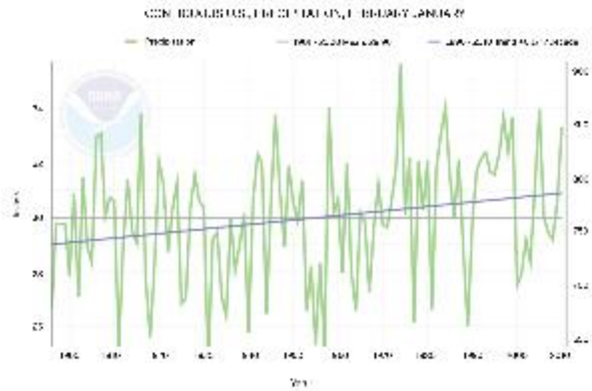

Figure 2. Average annual precipitation 1900-2010 for the contiguous United States. Credit: Wright Seneres based on NOAA data.

Figure 1 shows average temperatures in the United States per year. The purple line connects the temperature data for each year. The blue line shows the increasing temperature trend. Figure 2 shows average precipitation in the United States per year. The green line connects the precipitation data for each year. The blue line shows the increasing precipitation trend.

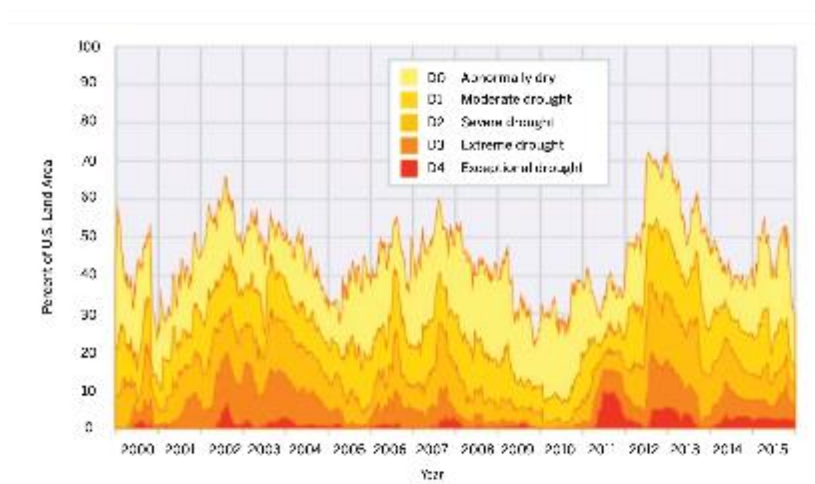

Figure 3. The percentage of land in the United States in drought 2000-2015. Credit: Wright Seneres based on EPA data.

Figure 3 shows the percentage of lands in the United States that experienced drought. These droughts occurred even though there was more rainfall during this time (see Figure 2).