Journal of Applied Science and Education, 2025,
Vol. 05, Iss. 01, S. No. 089, pp. 1-11
ISSN (Online): 2583-1372

Impact of Climate Change on Water Resources: A Review

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How to cite this paper: N. Jain and N. Agnihotri, "Impact of Climate Change on Water Resources: A Review," *Journal of Applied Science and Education (JASE)*, Vol. 05, Iss. 01, S. No. 089, pp 1-11, 2025.

https://doi.org/10.54060/a2zjournals.jase.89

Received: 12/01/2025
Accepted: 18/01/2025
Online First: 20/04/2025
Published: 25/04/2025

Abstract

Climate change is the increase in Earth's mean temperature and the corresponding significant modifications to weather patterns. Climate and water are inextricably linked. Water gets more scarce, polluted, and unreliable as a result of severe weather conditions. Resources of water are projected to be impacted by climate change, which has an impact on precipitation quantity, variability, timing, form, and intensity. Rising global temperatures result in more water evaporating, which raises the amounts of water vapor in the atmosphere, leading to more frequent, intense, and violent rainstorms in the years to come. Temperature and precipitation variations are the primary ways of climate change that modify the hydrological cycles, which could exacerbate regional and worldwide water shortages. Therefore, the main cycle through which climate change occurs is weather and water, specifically the delicate balance between evaporation and precipitation. Water management techniques and the operation of current water infrastructure, such as irrigation, drainage, flood defenses, and hydropower, are all impacted by climate change. Current climate projections indicate that safeguarding the water will require controlling its effects, whether excessive or insufficient and taking the necessary steps to reduce the vulnerabilities of businesses and communities. The correlation between climate change and water resources is discussed in this review. Evaluating the availability of water resources in light of future national needs and the predicted effects of climate change and its variability is essential for long-term development on both a national and global scale. Consequently, it is clear that there are intricate connections between the climate, water, biophysical and socioeconomic systems. Therefore, human society, especially in Rajasthan is primarily concerned about the interaction between change of climate and water resources, particularly freshwater.

Keywords

Climate Change, Water, Temperature, Precipitation, Freshwater, Hydrology

COMMON ABBREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
UN WWDR	United Nations World Water Development Report
SSA	Sub – Saharan Desert
UNECA	United Nations Economic Commission for Africa
BCM	Billion Cubic Metres
NWM	National Water Mission
CCAR	Climate Change Agenda for Rajasthan
RAPCC	Rajasthan Action Plan on Climate Change
UNFCC	United Nations Framework on Climate Change
NDC	National Determined Contributions
NAP	National Adaptation Plan Process

1. Introduction

The world of today is always evolving. A worldwide issue, climate change has a variety of national and subnational ramifications due to its effects on a range of industries, including infrastructure, energy, forestry and biodiversity, agriculture, water resources, and human health. Climate change is one of the primary determining factors when scientists assess the quantity and quality of water resources.

One common example of a universal good is WATER. The significance of water doesn't need to be explained: water is life. Global droughts and floods are becoming more severe due to climate change, which is already affecting people's access to water. By affecting the amount, precipitation location, and timing, it affects the water cycle. By changing rainfall patterns, rising temperatures, and modifying the timing of snowfall and glacier melt, climate change also has a significant impact on water resources by changing the seasonality of drainage flows.

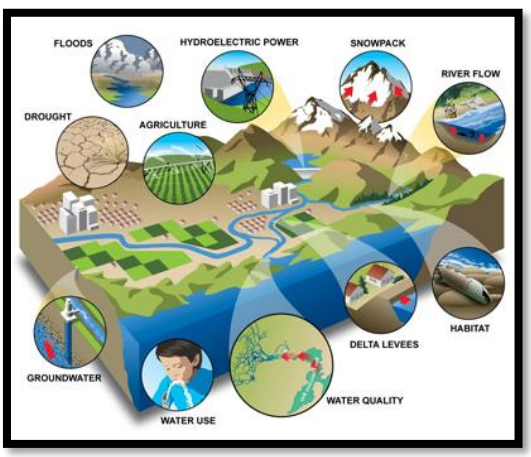

Figure 1. Model of Hydrologic Stimulation

2. Key Points

- Climate change poses a serious threat to the depletion of freshwater, which accounts for only 0.5% of the world's water supply. The previous 20 years have seen a 1 cm yearly drop in terrestrial water storage, including ice, snow, and soil moisture which has substantially influenced water security.
- Recent events in more than a fifth of the world's basins have involved significant rises in surface water area, indicating water damage, the expansion of reservoirs, and newly submerged land, or immediate decreases in surface water area, indicating the drying up of wetlands, reservoirs, seasonal water bodies, lakes, and floodplains.
- New climate change mitigation commitments for 2030 must be four times as ambitious to keep global warming to 2°C and seven times as ambitious to continue on pace to keep it to 1.5°C.

3. Climate and water on the global Agenda for Sustainable Development

An estimated 3.6 billion people on Earth currently live in areas where at least one month of the year may see a water scarcity. The United Nations World Water Development Report predicts that by 2050, this figure will fluctuate between 4.8 and 5.7 billion.

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) assesses how change of climate is affecting hydrology.

These papers offer the most comprehensive information on observed and projected climate change-related hydrological changes, including the following:

- There could be a big impact on water supplies if global warming is reduced to 1.5 °C over pre-industrial levels rather than 2°C because it could lower the percentage of the worldwide population that is subject to an increase in water stress brought on by climate change by as much as 50%.
- As greenhouse gas (GHG) concentrations rise, freshwater-related climate change hazards rise sharply. According to the most recent modeling studies, a reduction of at least 20 percent in renewable water supplies is expected to affect roughly 7% of people on the planet for every degree of global warming.

4. Impacts of water-related climate change, both observed and anticipated

1. Precipitation: Modern climate prediction models suggest that increasing temperatures would both increase evaporation and worsen the Earth's water cycle, causing certain land areas to dry up and storms to become more frequent and powerful. In many places, it is anticipated that increased precipitation intensity and variability will raise the hazards of drought and flooding. Therefore, areas farther away from storm tracks are likely to have less precipitation and a greater risk of drought, whereas areas affected by storms are likely to experience more precipitation and a higher risk of flooding. Precipitation is consistently predicted to increase at high latitudes (very likely) and parts of the tropics, while decreasing in some subtropical and lower mid-latitude regions (likely) by 21st-century climate model simulations.

2. Cryospheric water resources: Ice sheets, ocean, river or lake ice, ice cover, ice shelves permafrost, glaciers and sporadic glaciers are all components of the cryosphere, which is an essential component of the climate system. These delicate water reserves react quickly to the continuous changes in the climate. In cryospheric river basins, this results in higher runoff and discharge peaks.

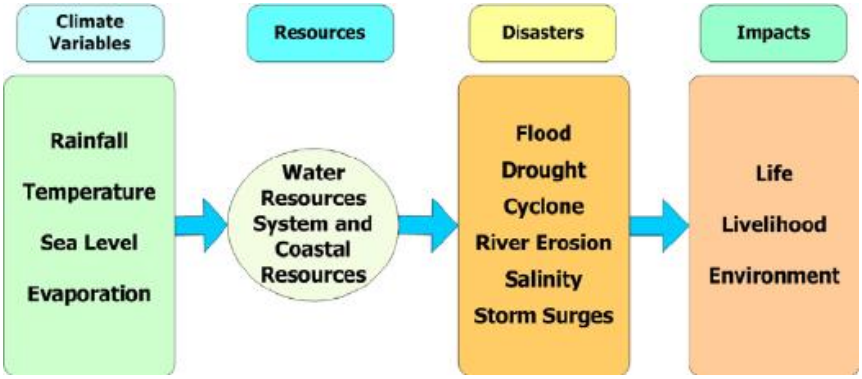

Figure 2. Climate Change's Effects on Water Resources

3. Surface water resources: Variations in climate variables, including evapotranspiration, precipitation, temperature, and others, can significantly affect surface water supply. Runoff and water availability are impacted by these changes, which in turn have an effect on river flow patterns. Stream flow, one of the most important components of the hydrological cycle, is highly susceptible to climatic shifts, which may become even more important in the future.

4. Groundwater resources: Climate influences on groundwater are harder to understand than those on surface water. The quantity and quality of groundwater systems are affected by climate change. Climate factors influence the percolation, infiltration of soil, and groundwater recharge rates in terms of quantity. Because climate change alters hydrological processes, groundwater quality is at risk. Additionally, rising temperatures alter the biological, chemical, and physical characteristics of groundwater, thereby compromising its quality. Other adverse consequences of global warming include changes in the amount and groundwater recharge timing as well as variations in groundwater levels. The region's surface water-groundwater link is ultimately impacted by these variations in groundwater levels

5. Case Study 1: Africa

Africa is probably where climate change will have the biggest effects. A large portion of Africa's current food insecurity, slow economic progress, and poverty can be ascribed to climate variability. Rainfall intensity, frequency, and trends would all reach extreme levels in African regions due to climate change's increased variability in hydrological and weather characteristics. There will be increasing water stress as droughts, floods, and storms become more severe and frequent.

According to certain research conducted in various parts of Africa, a 1oC increase in temperature would result in a 10% decrease in runoff while maintaining a constant level of rainfall. Between 2050 and 2100, there is a considerable chance that climate change will have an impact on stream flow throughout Africa. This impact might vary from 15% decreases in stream flow to 5% increases over the baseline of 1961–1990. The range of predictions for 2100 is between a 19% decline and a 14% gain. Africa has several challenges in the future years related to water and climate change. Coastal areas are influenced by the rise of sea level; temperature increases, increased demands of water, decreased water use efficiency,likely decreased productivity, and crop water budget imbalances; population growth and rain-fed agriculture insecurity lead to increased irrigation water demand; changes in runoff and soil moisture; and an elevated degree of unpredictability regarding river flows that could have a significant impact on hydropower schemes.

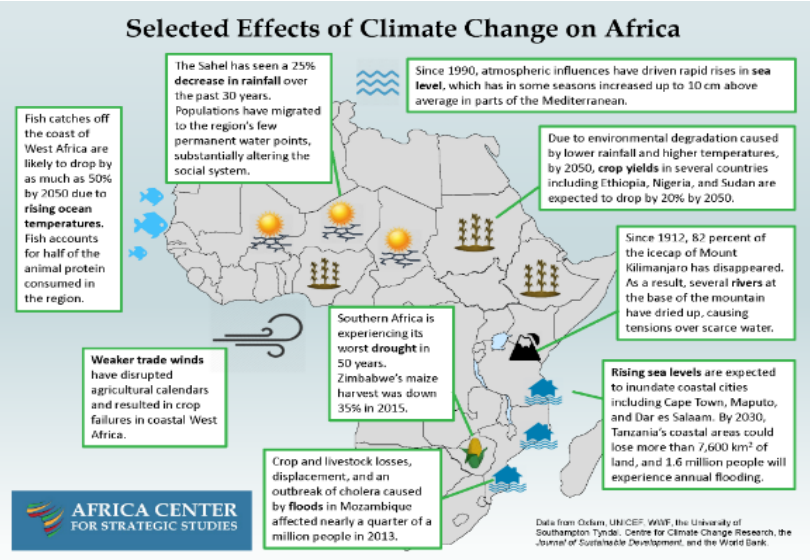

Figure 3. Some African Perspectives on Climate Change and Human Displacement

Water resources' susceptibility to the consequences of climate change: Already Africa is vulnerable to weather and climate change, which, when combined with other stressors, results in different levels of climate vulnerability in different regions of the continent. Complex marine and terrestrial interactions regulate the continent's climate, creating a range of conditions in different locations (from the humid tropics to the hybrid dry SAHARA, for example). At regional, municipal, and household levels, the climate has a major impact on the daily economic growth of Africa, especially in the areas of agriculture and water resources. The lack of infrastructure to supply a consistent water supply for agriculture, drinking, and other uses, along with the lack of governance capacity, are major issues facing Africa's water sector. The continent's water supply, accessibility, and demand may be further strained by climate change and fluctuation.

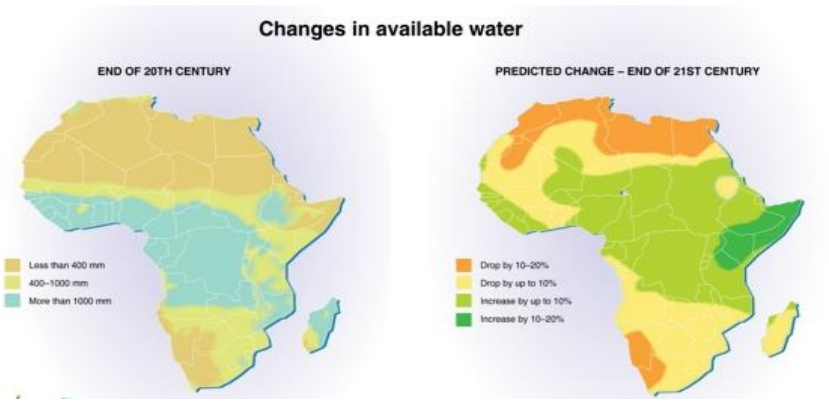

Figure 4. Variations in Africa's water supply during the final decades of the 20th and 21st centuries

The Impact of Climate-Induced Water Disturbances on African Human Development: In Africa, water is a vital and crucial resource for many different industries. Climate-related changes to Africa's water resources are also predicted to harm biodiversity owing to both direct and indirect impacts of shifting land cover and use. According to research, the decline in rainfall caused farmers to search for alternative farming sites, which contributed to 2.3% of Kenya's forest losses. Changes in rainfall patterns will have an impact on human development in Africa by lowering the amount of water available for grazing, crops, cattle, economic activity, soil fertility, and moisture constant. Water is essential and closely related to agriculture. In most pastoral areas, severe drought has a direct impact on water supplies and the availability of animal feed, which results in a significant loss of cattle. Climate change thus poses a challenge to human growth in terms of livelihood and security.

Africa's View on the Climate and Water: Addressing climate change and its repercussions requires comprehensive, multidisciplinary approaches. The predicted impacts of climate change on Africa's water sector are severe, with an increase in the probability of catastrophic weather (such as severe drought and flooding) leading ponds, lakes, and rivers to dry up. The African continent must improve its productive involvement in climate debates and encourage the implementation of climate change and mitigation plans into national and sub-regional developmental strategies, programs, and activities of member nations. African nations must also take the lead in setting the agendas for climate and water resource-related measures in order to avoid the long-term effects of climate change on the continent. They must also understand the need to reduce greenhouse gas emissions globally, boost investments that give people access to sustainable and reasonably priced cleaner energy, and upgrade water infrastructure, especially for rural areas. Last but not least, they need to increase their readiness and swiftly adjust to climate-related water disasters, improve economic and social resilience, and transform these difficulties into chances for the continent's economic and human advancement.

Figure 5. Water shortage in Africa

It is true that the severe economic water shortage is Africa's biggest problem. If left uncontrolled, climate change's detrimental effects on Africa's water resources might lead to food and nutritional shortages, deteriorating health and economic conditions, and an increase in poverty.

6. Case Study 2: Rajasthan

- Even though climate change is making weather patterns more unpredictable and causing more catastrophic weather events, India is still vulnerable to droughts and floods. Water consumption in India has already grown significantly

over time as a result of fast industrialization, economic development, population growth, urbanization, and agricultural expansion.

- The largest state in India, Rajasthan, is located in an area that is extremely sensitive to the climate. Desert covers a large area of the state. It encompasses much of the huge, unfriendly Great Indian Desert (sometimes called the Thar Desert), with a margin that goes parallel to the Sutlaj Indus river basin. Rajasthan experiences hot, dry weather most of the time. The state as a whole has very little rainfall. The Thar Desert is characterized by high temperatures of the air and soil, intense solar radiation, high wind speeds, and sporadic and erratic rainfall.
- The state's physical and socioeconomic structure will probably be significantly impacted by the fluctuations of the climate. Rajasthan has seen more severe and regular droughts than any other Indian region in recent years.
- Rajasthan only shares 1.16 percent of the nation's water resources, although making up 10.5% of its total land area. Nearly 70% (2/3rd) of the state is categorized as desert or semi-arid, making it the driest state. Water scarcity has always existed in Rajasthan. The typical rainfall is 531 mm, compared to the 1200 mm national average, and 380 mm in desert regions (State Water Policy). On average, western Rajasthan receives less than 100 mm to over 400 mm of rain, and eastern Rajasthan receives 220 mm to 1020 mm.
- In addition to being limited, the state's water resources are also extremely unevenly distributed in terms of time and area, with the majority of them being found in the southern and southeast regions of the state.

Figure 6. Revealing the Real Worth of Water: India's Drought Situation

- In the state, surface water resources are scarce and in a vulnerable state. There is just one perennial river in the state, Chambal, and all of the other rivers are rain-fed. Of the 21.71 BCM of surface water that is accessible in the state, 16.05 BCM can be used economically. The fact that the state has so far harvested 11.84 BCM suggests that surface water supplies will eventually become very scarce.
- In contrast to the national average of .001 BCM by 2050, it is predicted that water availability will drop below .00045 BCM by that time. Water shortage is indicated by water availability below .001 BCM, as per the international standards established by IWS.
- The geochemistry of water has changed negatively as a result of excessive groundwater extraction. In the nation, 42% of saline-affected areas and 51% of fluoride-affected areas are in Rajasthan. According to WHO drinking water quality recommendations, approximately 56% of Rajasthan's water sources are unfit for human consumption.

- With recurrent droughts occurring every three to four years throughout a five-year cycle, the state has the highest likelihood of experiencing drought in India. According to the Rajasthan State Action Plan on Climate Change, droughts will become more frequent in the state, which will affect not only water supplies but also other reliant industries and related livelihoods.
- Along with the west-flowing rivers of SAURASTRA and Kutch, which make up almost 60% of Rajasthan's land area, climate change will cause the river LUNI to experience severe water stress.

Figure 7. Luni River Path

Variation of Rainfall: According to historical data for the state, the average rainfall in Western Rajasthan ranges from less than 100 mm to more than 400 mm, while in Eastern Rajasthan, it ranges from 220 mm to 1020 mm. Mount Abu in the Sirohi district receives the most rainfall in the Southwest, as well as in the lowlands districts of Banswara and Jhalawar. According to the regional model, the average annual rainfall will somewhat decline.

Extreme Climate: According to Floods and Droughts observational records, the Western Rajasthan region has had a high risk of experiencing severe and very severe droughts for more than a century. The southern areas of Rajasthan have already seen numerous severe droughts despite having high average rainfall. Flash floods have occurred in several locations in Rajasthan as a result of intense rainfall storms. Examples include the floods that occurred in July 1981 in Jaipur, Tonk, and Nagaur, as well as in 2006 over Barmer.

Variation of Temperature: According to a review of historical data for extreme weather events over the last 100 years, Rajasthan has seen the most cold waves, second only to Jammu and Kashmir. The annual mean surface temperature is expected to rise by 2-4OC for the state of Rajasthan and by 2-4OC for the rest of India, according to high-resolution regional model estimates for 2071–2100.

Quality of Water Deteriorates: The geochemistry of water has changed negatively as a result of excessive groundwater extraction. The concentration of naturally occurring pollutants including fluoride, nitrate, and chloride salts in groundwater that is being exploited is rising. Twenty million people in the state are impacted by the poor quality of the water in more than 75% of the communities and habitations. Approximately 56% of all water sources are unfit for human consumption, according to WHO drinking water quality recommendations. Because there is less surface water available and demand is increasing, climate change will lead to more groundwater extraction, which might further degrade groundwater quality and have detrimental impacts on human health.

Rajasthan Environment Mission and Climate Change Agenda: As the largest state in the nation, Rajasthan has unique vul-

nerabilities related to exposure to climatic extremes and varying capacities to respond to the likely risks. The creation of the Climate Change Agenda for Rajasthan (CCAR) was a significant first step in addressing climate risks. Other opportunities that can be taken advantage of include harnessing solar energy.

National Water Mission: The Mission will create a framework to maximize water use by raising water use efficiency by 20% while taking the National Water Policy's provisions into consideration. The following are the five objectives that NWM has identified:

- An extensive public water database and an evaluation of how climate change is affecting water resources.
- Encouragement of state and citizen efforts to preserve, increase, and conserve water.
- Concentrated attention on regions that are at risk, such as those that are overexploited.
- Fostering integrated water resources management at the basin level.

7. Mitigation and Adaptation

- Enhancing the Storage of Carbon
- Natural buffers safeguarding
- Rainwater Harvesting
- Implementing climate-conscious farming.
- Conservation of wastewater
- Using Groundwater: Groundwater has been contaminated and abusedin many places, while in others, its amount is unknown. To meet the needs of a growing population and adjust to the changing environment, groundwater must be explored, preserved, and used responsibly

8. Effective ideas

Within and across sectors, the following policies and initiatives are suggested for water-smart climate adaptation and mitigation measures:

- Climate and water agreements and processes on a global and regional level
  - Facilitate the participation of a wider range of national and local government agencies and ministries, including those from the water, health, energy, and agriculture sectors, in international and regional climate events and workshops by utilizing already-existing platforms like the UNFCCC regional climate weeks or the NDC Partnership.
  - Establish criteria and create a set of global priorities for climate-resilient water and sanitation interventions in particular hotspots based on accepted scientific observations and projections of the effects of climate change. These priorities should prioritize the world's most vulnerable, exposed, and underserved rural and urban populations as well as regions that are experiencing significant pressures from human displacement.
  - As a way to reduce GHG emissions, make sure the role that water plays in mitigation is adequately represented in climate talks and accords. Restoring and conserving damaged eco-hydrological systems is part of this. All plans and initiatives related to climate change, including regional and national development plans, must include water protection.
  - Involve and empower young people and water professionals, especially Indigenous youth, as leaders and experts who offer solutions for climate change and water security that uphold, defend, and advance the basic human rights to water.

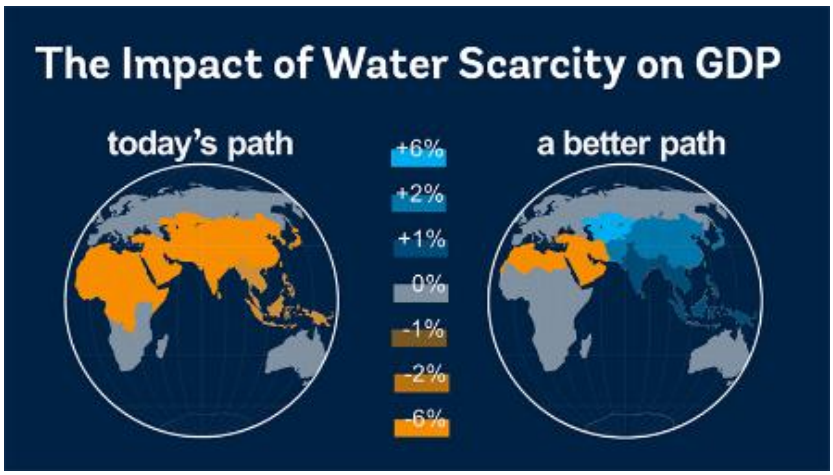

Figure 8. Impact of Water Scarcity on GDP

- Developing national and subnational capability, implementing plans, and keeping an eye on
  - When applicable, include risk-based approaches to water provision and management practices that are in line with climate mitigation and adaptation targets into current NDCs, NAPs, and other national, subnational, and local climate initiatives.
  - Create or improve systems at the national level to encourage closer communication between the water and climate/environment ministries.
  - To guarantee that choices taken today do not worsen future water stress for marginalized and vulnerable groups, support the development of institutional capacity for the application of current risk-based methods to climate change adaptation and mitigation at the project and decision-making levels.
  - Encourage research by academics and partnerships with public and private organizations that make investments in climate-resilient, context-specific, low-regret water resources infrastructure and technologies.

9. Conclusion

Therefore, water both facilitates and hinders humanity's capacity to lessen and adapt to climate change. Approaches to risk and ecosystem-based management that guarantee the significant and productive involvement of impacted individuals provide no- or low-regret solutions that can be modified over time as underlying circumstances evolve. In addition to being a moral requirement for the benefit of future generations who did nothing to contribute to the climate catastrophe they will inherit, enhancing the resilience of freshwater ecosystems is crucial for adaptation today. There is a rare chance to improve the coherence of the international frameworks humanity has established to create a sustainable future for everybody, as well as to change the current governance and management systems. Inaction is not justified by uncertainty because there are currently tools, strategies, and funding sources accessible. We have no time to wait.

Food access, availability, use, and stability are anticipated to be influenced by variations in water quality and quantity brought on by change of climate. Water management techniques and the operation of current water infrastructure, such as irrigation, drainage, flood defenses, and hydropower, are all impacted by climate change.

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