Turkish Journal of Computer and Mathematics Education (TURCOMAT) Volume 15, Issue 2(2024),104- 116

Research Article

Chemical Perspectives on the Impact of Climate Change in Afghanistan: A Comprehensive Review

Zardar Khan[a*], Noorzaman Bawari[b] , Shukrullah Wadeer[b], Mohammad Jawad Niazi[c], Nazar Mohammad Nazar[b], Safir Ullah Aftab[a]

[a] Department of Chemistry, Faculty of Science, Nangarhar University, Nangarhar, Afghanistan
[b] Department of Mathematics, Faculty of Science, Nangarhar University, Nangarhar, Afghanistan
[c] Department of Physics, Faculty of Science, Nangarhar University, Nangarhar, Afghanistan
[*]Corresponding author email: patwarc@gmail.com

Abstract: Climate change is a global phenomenon that has significant impacts on various aspects of human life, including the environment, economy, and social well-being. Afghanistan, one of the least developed and most vulnerable countries to climate change, is facing alarming effects due to its high dependence on agricultural livelihoods, fragile environment, poor socio-economic development, high frequency of natural hazards, and over four decades of conflict. This comprehensive review aims to provide an overview of the current state of knowledge on the impact of climate change on Afghanistan's environment, economy, and society, and to highlight the vulnerability of Afghanistan to climate change. The review also explores the chemical composition of air pollutants in Afghan cities, the impact of air and water pollution on human health and the environment, the influence of climate change on soil composition and nutrient availability, and the implications for water resources, including groundwater quality and availability. Finally, the review discusses the chemical aspects of climate change adaptation and mitigation efforts in Afghanistan, focusing on innovative technologies and practices to address climate-related challenges in the country.

Keywords: Climate Change, Medicinal Plants, Biodiversity, Chemical Aspects, Water Quality, Soil Chemistry, Hydrochemistry.

1. Introduction

Climate change is a global phenomenon that has significant impacts on various aspects of human life, including the environment, economy, and social well-being. Even under the most optimistic scenarios for limited global greenhouse gas emissions, Afghanistan will have to adapt to steep temperature increases and changes in precipitation patterns(Aich & Khoshbeen, 2023; *How Air Pollution Affects Our Health*, 2023). Rising temperatures are rapidly altering precipitation patterns across Afghanistan, diminishing people's access to water, and making it among the world's most vulnerable countries to climate change (*Afghanistan: The Alarming Effects of Climate Change | OCHA*, 2023). Climate change will make it extremely challenging to maintain any economic and development gains achieved so far in Afghanistan (WFP et al., 2016). This comprehensive review on Chemical Perspectives on the Impact of Climate Change in Afghanistan aims to provide an overview of the current state of knowledge on the impact of climate change on Afghanistan's environment, economy, and society.

Afghanistan is one of the least developed and most vulnerable countries to climate change, facing alarming effects due to its high dependence on agricultural livelihoods, fragile environment, poor socio-economic development, high frequency of natural hazards, and over four decades of conflict (Snyman, 2020). The country ranks fourth on the list of countries most at risk of a crisis and eighth on the Notre Dame Global Adaptation Index of countries most vulnerable and least prepared to adapt to climate change(*Afghanistan: The Alarming Effects of Climate Change | OCHA*, 2023). Afghanistan faces rates of warming higher than the global average, with a potential rise of 1.4°C–5.4°C by the 2080s and 2090s, compared with the baseline of 1986–2005, making it extremely susceptible to the impacts of climate change (*Afghanistan - Climatology | Climate Change Knowledge Portal*, 2023).

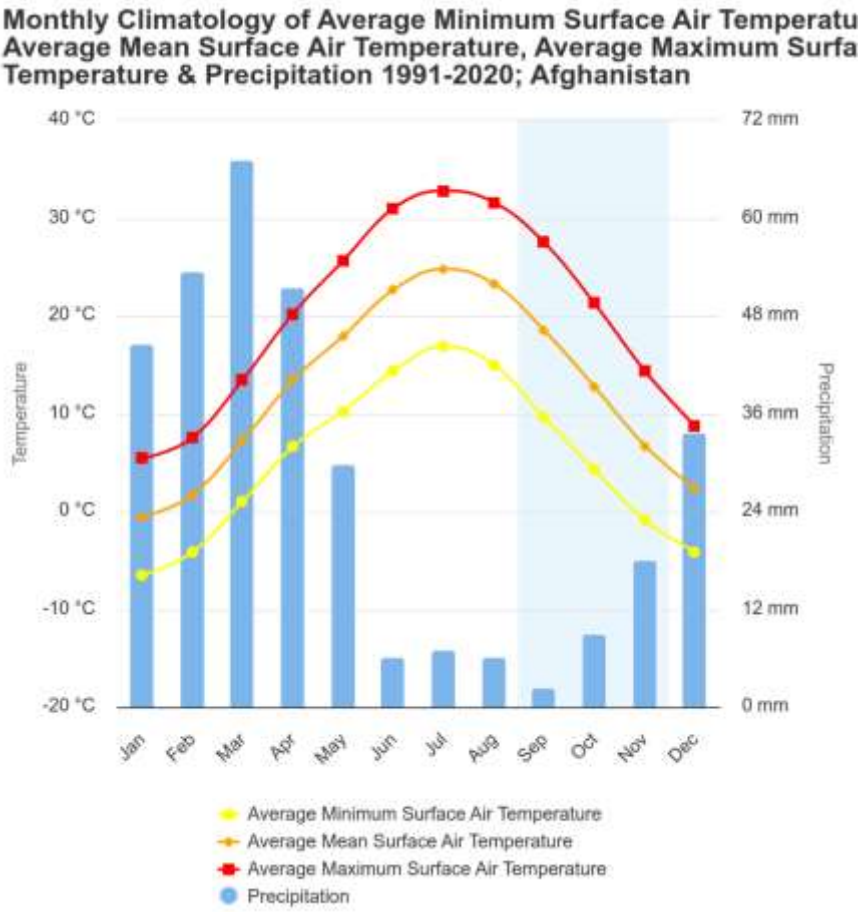

Figure 1: The figure presents the monthly climatology of Afghanistan for the period 1991-2020, showing average minimum, mean, and maximum surface air temperatures along with precipitation levels. The temperature data is illustrated by three lines: the yellow line for average minimum temperature, the orange line for average mean temperature, and the red line for average maximum temperature. These temperatures range from below -10°C in January to above 30°C in July. The precipitation is represented by blue bars, with the highest levels occurring in March and April at approximately 60 mm, and the lowest levels occurring from June to September.

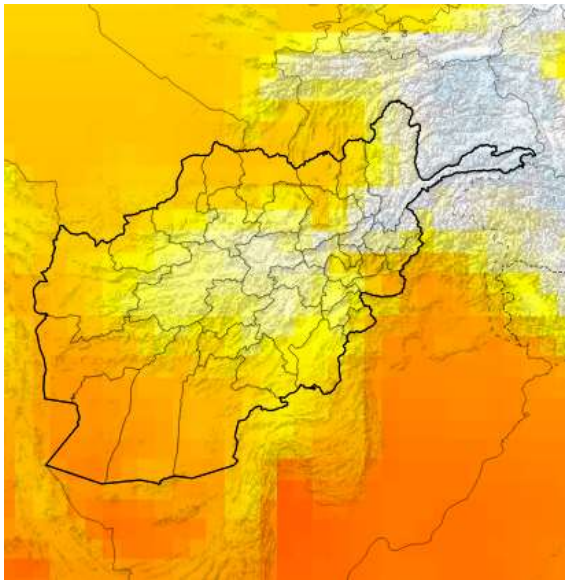

Figure 2: Average Mean Surface Air temperature of Annual From 1991-2020

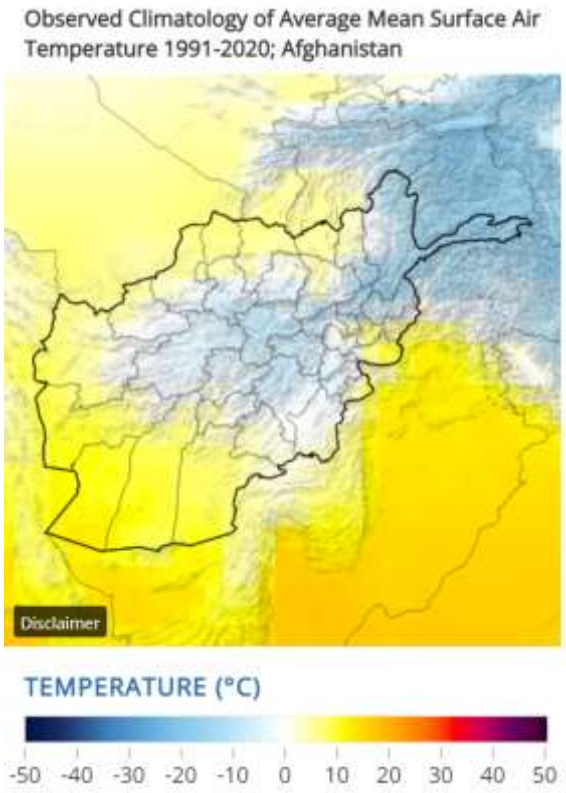

Figure 3: DEC-JAN-FEB Observed Climatology of Average Mean Surface Air Temperature 1991-2020; Afghanistan

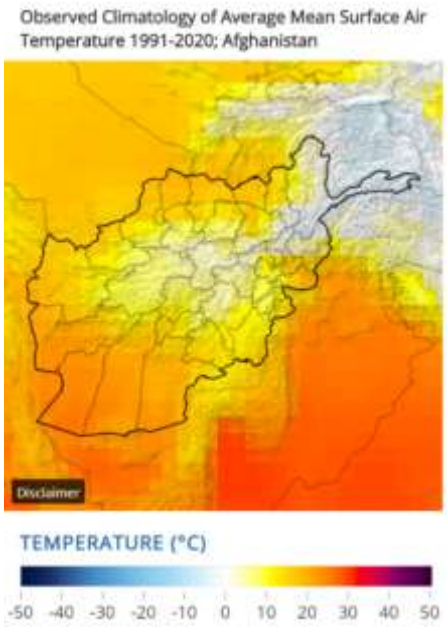

Figure 4:MAR-APR-MAY Observed Climatology of Average Mean Surface Air Temperature 1991-2020; Afghanistan

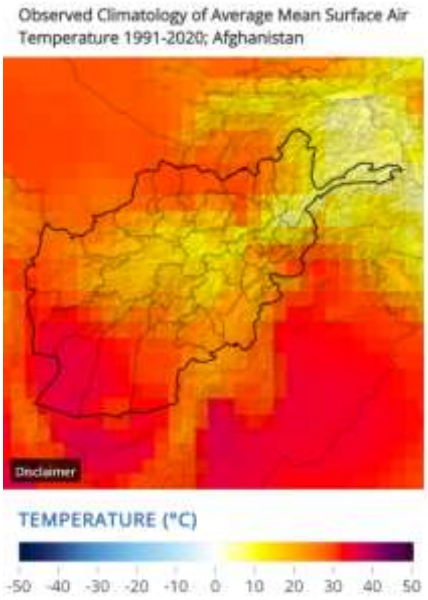

Figure 5: JUN-JUL-AUG Observed Climatology of Average Mean Surface Air Temperature 1991-2020; Afghanistan

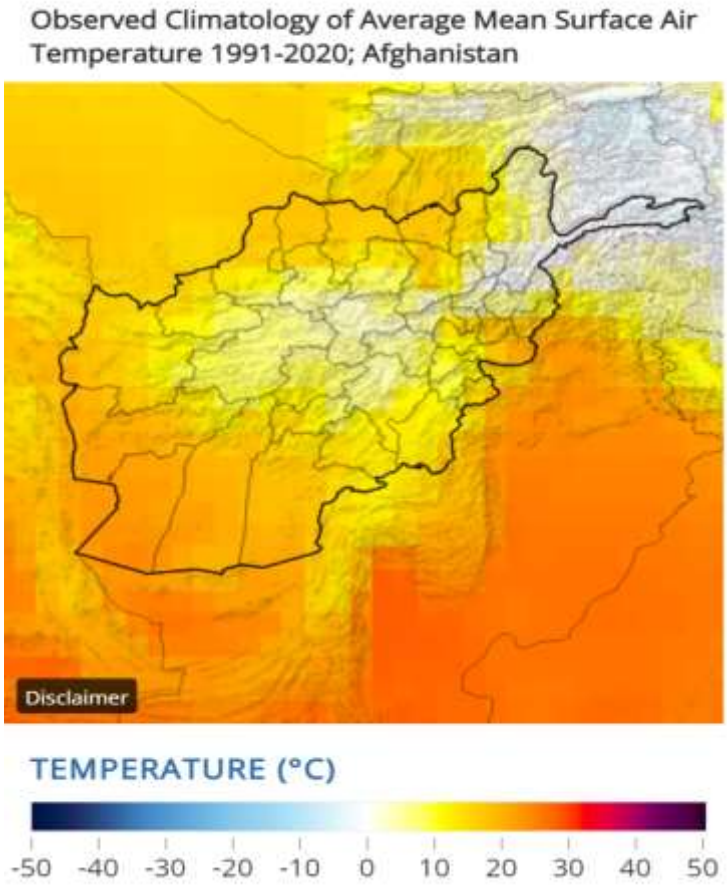

Figure 6: SEP-OCT-NOV Observed Climatology of Average Mean Surface Air Temperature 1991-2020; Afghanistan

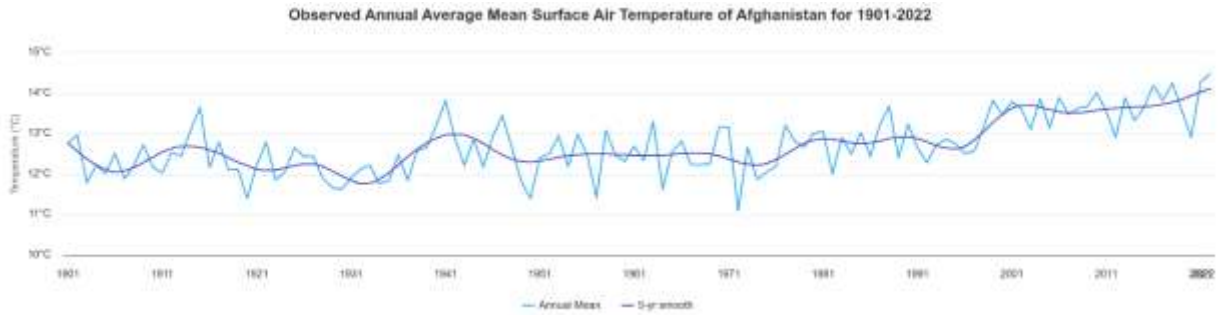

Figure 7: The graph shows the observed annual average mean surface air temperature in Afghanistan from 1901 to 2022. The annual mean temperature is represented by the light blue line, which exhibits fluctuations throughout the period. A darker blue line represents a 5-year smoothed trend, highlighting the overall increase in temperature over time. The data indicates a gradual warming trend, with temperatures rising from around 12°C in the early 1900s to approximately 14°C by 2022.

The purpose of this comprehensive review is to provide an overview of the current state of knowledge on the impact of climate change on Afghanistan's environment, economy, and society. The review aims to highlight the vulnerability of Afghanistan to climate change, which is one of the least developed and most vulnerable countries to climate change, facing alarming effects due to its high dependence on agricultural livelihoods, fragile environment, poor socio-economic development, high frequency of natural hazards, and over four decades of conflict. The scope of the review includes an assessment of the current state of knowledge on the impact of climate change on Afghanistan's environment, economy, and society, as well as potential adaptation strategies and priorities for action based on national strategies and plans

Materials and Methods

The materials and methods for the comprehensive review "Chemical Perspectives on the Impact of Climate Change in Afghanistan" involve a comprehensive assessment and planning, policy development, data collection and analysis, and a multi-faceted approach to addressing climate-related challenges in Afghanistan. The Afghanistan Vulnerability and Adaptation Technical Assessment Report aims to identify the main impacts of climate change on important sectors and propose priorities for adaptation action based on national strategies and plans. The Comprehensive Migration Policy (CMP) addresses the impacts of climate change, displacement, and migration in Afghanistan. The National Capacity Needs Self-Assessment for Global Environmental Management (NCSA) and the Climate Change Science Perspectives report provide valuable information for identifying key adaptation needs, potential adaptation options, and evaluation criteria. The review includes an assessment of the current state of knowledge on the impact of climate change on Afghanistan's environment, economy, and society, as well as potential adaptation strategies and priorities for action based on national strategies and plans. By integrating chemical aspects into adaptation and mitigation strategies, Afghanistan is working to build resilience and reduce the impacts of climate change on its people and ecosystems.

Climate Change in Afghanistan

Climate change is having significant impacts on Afghanistan, a country that is already facing various challenges related to security, poverty, and underdevelopment. The country is experiencing several key climate change trends and data-specific issues:

1. **Rising Temperatures:** Afghanistan faces rates of warming higher than the global average, with a potential rise of 1.4°C–5.4°C by the 2080s and the 2090s, compared with the baseline of 1986–2005(WBG & ADB, 2021) .
2. **Increased Drought and Floods:** The country is experiencing an increase in drought due to low precipitation and reduced snowfall, as well as more frequent floods due to heavy and uneven rainfall, which has increased by between 10 percent and 25 percent over the last 30 years (Sayed & Sadat, 2022).
3. **Warmer Temperatures:** The average temperatures in Afghanistan are on average 1.8 degrees Celsius higher than in 1950 (*Climate Change Compounds Longstanding Displacement in Afghanistan - Afghanistan | ReliefWeb*, 2023).

These climate changes are affecting the country's environment and society in several ways:

- **Impact on Agriculture:** Climate change is affecting farmers and pastoralists in different regions across Afghanistan, leading to reduced crop yields and livestock losses (Safi et al., 2024; Sayed & Sadat, 2022).

- **Displacement:** Droughts and floods have prompted mass movements, leaving about 4 million people in need of humanitarian assistance in 2018[2]. In 2018, Afghans were displaced more often due to environmental and natural disasters than conflict (*Climate Change Compounds Longstanding Displacement in Afghanistan - Afghanistan | ReliefWeb*, 2023; Sayed & Sadat, 2022).

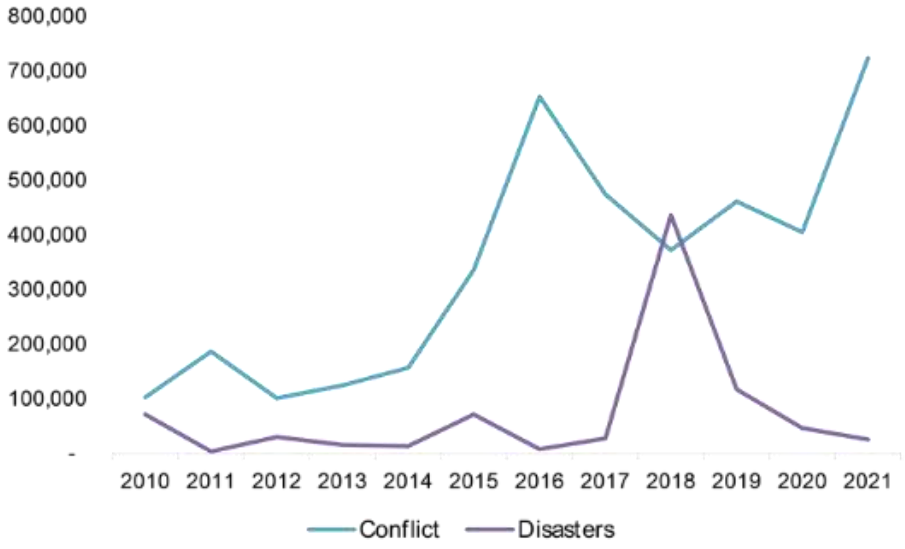

Figure 8: Internal Displacements in Afghanistan by Cause, 2010-21

- **Health Risks:** Climate change is exacerbating health risks, as people are exposed to more frequent and severe weather events, such as floods and droughts (WBG & ADB, 2021).

- **Economic Impact:** The economy is also feeling the effects of climate change, as reduced agricultural productivity and increased natural disasters lead to decreased economic growth and development (Jawid & Khadjavi, 2019).

To address the challenges posed by climate change, Afghanistan needs to develop and implement effective policies and strategies. Some efforts have been made to develop new climate change projections to fill the existing gap of scientifically robust climate data in Afghanistan, with the aim of mainstreaming climate change into the country's development process (Environment, 2016). The Comprehensive Migration Policy (CMP) is one such policy that addresses the impacts of climate change, displacement, and migration in Afghanistan (Sayed & Sadat, 2022). However, more efforts are needed to strengthen the country's resilience to climate change and develop effective mitigation and adaptation measures.

Chemistry of Air and Water Quality in Afghanistan

Air and water quality in Afghanistan are significant concerns, with both experiencing changes that impact human health and the environment.

Air Quality

Air pollution is a major issue in Afghan cities, with Kabul experiencing some of the worst air quality in the world. In 2019, Kabul had an annual PM2.5 concentration of 58.8 μg/m³, placing it in the "unhealthy" category, which requires PM2.5 concentrations between 55.5 to 150.4 μg/m³ (Afghanistan Air Quality Index (AQI) and Air Pollution Information | IQAir, 2024) . Afghanistan ranked fourth in a list of most polluted countries, just behind Mongolia, Pakistan, and Bangladesh(Afghanistan Air Quality Index (AQI) and Air Pollution Information | IQAir, 2024).

Kabul's air quality is influenced by various factors, including rapid urbanization, poor-quality fuel, burning trash, industrial activities, and household cooking stoves (Gasping for Air in Kabul, 2023).

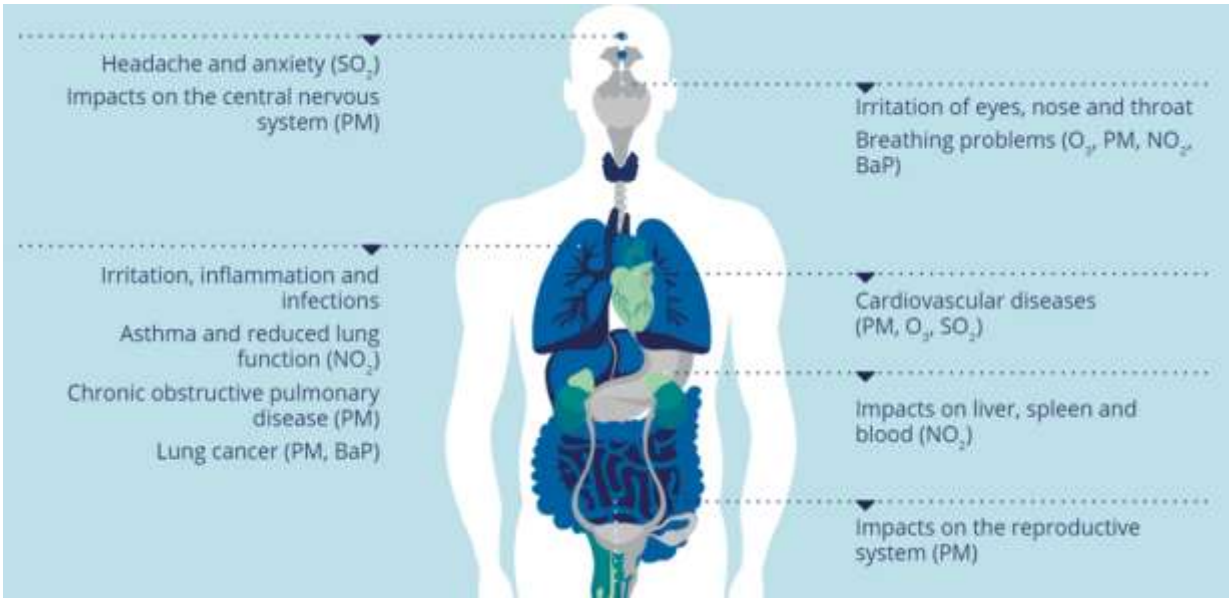

Figure 9: Health impacts of air pollution

Water Quality

Water quality in Afghanistan is also a significant concern, with changes in water chemistry affecting both the quality and availability of water. A study conducted in the Kabul Basin found that groundwater consists primarily of two types, classified as calcium and magnesium bicarbonate and sodium and chloride types (Gasping for Air in Kabul, 2023). The chemical composition of groundwater is influenced by water-rock interactions (Afghanistan Air Quality Index (AQI) and Air Pollution Information | IQAir, 2024). The quality of drinking water in Afghanistan is affected by various chemical parameters, including pH, total dissolved solids, hardness, and nitrate (Rana et al., 2019; The Slow Violence of Pollution in Afghanistan - CEOBS, 2018).

Afghanistan is facing significant challenges related to air and water quality, which are having serious impacts on human health and the environment. The chemical composition of air pollutants in Afghan cities includes particulate matter, ozone, and indoor air pollution associated with the combustion of solid fuels. The impact of air pollution on human health is significant, with high levels of child mortality. Changes in water chemistry are affecting both the quality and availability of water, with groundwater in the Kabul Basin consisting primarily of two types or classifications. The impact of water pollution on human health and agriculture is significant, and more efforts are needed to address these challenges and develop effective mitigation and adaptation measures.

Impact of air pollution on human health and the environment

The impact of air pollution on human health and the environment is significant and multifaceted. Air pollution is responsible for more than 6.5 million deaths each year globally, and it has various long-term effects on human health, including chronic asthma, pulmonary insufficiency, cardiovascular diseases, and cardiovascular mortality (Manisalidis et al., 2020; National Institute of Environmental Health Sciences: Air Pollution and Your Health, 2023). Air pollution can also lead to infant mortality or chronic diseases in adult age due to its effects on early human life(Manisalidis et al., 2020).

Some of the key impacts of air pollution on human health include:

- Respiratory issues: Air pollution can cause short-term respiratory infections, leading to more school absences (*National Institute of Environmental Health Sciences: Air Pollution and Your Health*, 2023). Children living near busy roads are at increased risk for asthma(Patrick, 2016).

- Cardiovascular diseases: Long-term exposure to air pollution can increase the risk of heart attack (Patrick, 2016). Particulate matter with a diameter of 2.5 μm or less (PM2.5) is associated with an increased risk of stroke, chronic obstructive pulmonary disease, trachea, bronchus, and lung cancers(*How Air Pollution Affects Our Health*, 2023).

- Diabetes: A Swedish cohort study suggests that long-term air pollution exposure may induce diabetes(Manisalidis et al., 2020).

- Environmental effects: Air pollution can cause acid rain, which can acidify water and soil environments, damage trees and plantations, and even damage buildings and outdoor sculptures, constructions, and statues[1]. Haze, produced when fine particles are dispersed in the air, reduces the transparency of the atmosphere(Manisalidis et al., 2020).

To address these issues, comprehensive monitoring, effective policies, and sustainable management of air and water resources are required to ensure the well-being of the population and the environment.

Water chemistry

The chemical composition of water, including its quality and availability, is a critical aspect of environmental and public health. In Afghanistan, the quality and availability of water are influenced by various factors, including natural processes, human activities, and climate change. The chemical parameters most likely to be found in the groundwater in Afghanistan include minerals or salts such as calcium, sodium, bicarbonate, and chloride, as well as plant nutrients like nitrogen and phosphorus (Sundem, 2014).

A detailed assessment of groundwater quality in the Kabul Basin, Afghanistan, revealed that the groundwater consists primarily of two types or classifications based on major ion chemistry. The first group is classified as a calcium and magnesium bicarbonate type, while the second group is classified as a sodium and chloride type(Jawadi et al., 2020).

The impact of changes in water chemistry on human health and the environment is a growing concern, particularly in densely populated areas such as Kabul. Compromising the quality of ground and surface water endangers the health and safety of residents. Assessing the quality of water is mainly based on its physicochemical components, biological quality, and heavy metals concentrations (Saalidong et al., 2022).

In Europe, new evidence about chemical pollution and water scarcity are growing concerns. Climate change is amplifying water quantity and quality challenges, with more frequent and intense droughts and floods. Water scarcity is expected to worsen, especially in southern Europe, affecting all sectors. Groundwater supplies about 65% of drinking water in the EU, making it essential to address pollution and improve wastewater treatment to ensure clean and safe water resources (*Water Quality and Quantity Are Key for Well-Being*, 2023).

Soil Chemistry and Agriculture

The influence of climate change on soil composition and nutrientavailability

Climate change has significant impacts on soil composition and nutrient availability, which in turn affect agriculture and food security. In Afghanistan, the effects of climate change on soil properties and processes, as well as the corresponding influence on food security, are a growing concern. Some of the key impacts of climate change on soil chemistry and agriculture include:

1. **Soil erosion:** Climate change increases soil erosion, which damages soil properties essential for food production(Brevik, 2013).
2. **Soil moisture levels:** Climate change influences soil moisture levels through direct climatic effects (precipitation, temperature effects on evaporation) and climate-induced changes in vegetation and plant growth rates(Pareek, 2017).
3. **Soil salinity:** Rising sea levels and increased soil surface temperature can lead to increased soil salinity in coastal agriculture lands, negatively affecting crop productivity(Ullah et al., 2021).
4. **Soil fertility:** Climate change can lead to reduced soil fertility, which in turn affects agricultural productivity and food security(Hamidov et al., 2018).
5. **Pest infestations:** Climate change can create more favorable conditions for pests, leading to increased infestations and reduced crop yields(*Climate Change Impacts on Agriculture and Food Supply | US EPA*, 2023).

To address these challenges, it is crucial to develop and implement effective policies and strategies to adapt to the changing climate. Some potential adaptation strategies include crop rotation, integrated pest management, and the use of climate-resilient crop varieties. Additionally, research is ongoing to help prepare for a changing climate, including the development of new agricultural practices and policies(Food & Soil Health | Soil and Environmental Biogeochemistry, 2023).

Altered Soil Chemistry Affects Agricultural Practices And Food Security

Altered soil chemistry can significantly affect agricultural practices and food security. Soil degradation, for example, can drive food insecurity, and sustainable management is needed to address this issue (Pozza & Field, 2020). Climate change can lead to reduced soil fertility, which in turn affects agricultural productivity and food security. Soil erosion, another impact of climate change, can damage soil properties essential for food production(*Reimagining the Role of Chemistry in Food Security - American Chemical Society*, 2023).

To address these challenges, chemists are exploring new areas of innovation to meet the needs of a growing world population. Some examples include better growing techniques, regenerative farming, water use efficiency, drought-resistant crops, soil improvement practices, and precision agriculture. Sustainable soil management is also essential to maintain and increase food production, and through the practice of conservation agriculture, the rate of soil loss can be reduced to approximately equal the rate of soil formation(Parikh & James, 2012).

Healthy soils are foundational to sustainable food production, and food security is a major concern in the face of climate change, population growth, and planetary boundaries[5]. Therefore, it is crucial to develop and implement effective policies and strategies to adapt to the changing climate and ensure sustainable soil management practices to maintain and increase food production and food security(*Food & Soil Health | Soil and Environmental Biogeochemistry*, 2023).

Water Resources and Hydrochemistry

Climate change has led to significant shifts in hydrochemistry due to changes in precipitation patterns and glacial melt. These changes have had a profound impact on water resources and water quality. Here are some key findings from the provided sources:

1. **Reduced Dry-Season Water Availability:** Climate-induced shifts, such as decreasing snow cover and glacier mass loss, have led to reduced dry-season water availability in various regions. This is driven by factors such as increasing transpiration and earlier onset of snowmelt, contributing to drying in dry summer climates(*Chapter 4: Water | Climate Change 2022: Impacts, Adaptation and Vulnerability*, n.d.).
2. **Impact on Water Availability and Quality:** Changes in the location and amount of precipitation have affected water availability and quality. Increased precipitation can lead to higher water supplies, while reduced precipitation can decrease net water supplies, particularly due to predicted temperature rises causing increased evaporation rates. Changes in the timing, intensity, and duration of precipitation can also negatively affect water quality, leading to issues such as flooding, increased pollution, and sedimentation (*The Effect of Climate Change on Water Resources and Programs | Watershed Academy Web | US EPA*, 2023).
3. **Glacial Melt and Runoff:** In regions where glacial melt has increased runoff, this has benefited agriculture. However, the long-term implications of glacial mass loss on water resources and agriculture are a growing concern, particularly in areas where glacial runoff is a significant water source(Piao et al., 2010).
4. **Water pH and Quality:** Water pH is an important factor in determining water quality. Changes in pH can influence the availability of metals and other water quality parameters, impacting the overall quality of ground and surface water systems (Saalidong et al., 2022).

These findings underscore the complex and multifaceted impacts of climate-induced shifts in precipitation and glacial melt on water resources and hydrochemistry. It is evident that these changes have far-reaching implications for water availability, water quality, and the sustainability of agricultural practices, emphasizing the need for comprehensive monitoring and adaptive water resource management strategies.

Changes In Hydrochemistry Due To Climate-Induced Shifts In Precipitation And Glacial Melt

The response of the hydrological cycle to temperature changes in recent and distant climatic history has been a subject of study. The prevailing theory suggests that as temperature increases, the hydrological cycle is intensified, leading to more and heavier precipitation. However, the spatiotemporal distribution of this response is heterogeneous, making it difficult to quantify hydroclimate variability on a regional, continental, and global scale. Large-scale paleo-hydroclimatic shifts, especially during warm periods, require further investigation as they could provide new insights into present and future hydroclimate variability. In general, most paleoclimate records suggest that the hydrological cycle intensified in warmer climates and weakened during colder periods. However, the spatial distribution of these changes was not homogeneous. The impact of climate change on the cryosphere and hydrosphere in the Alps is expected to lead to a decrease in annual river discharge by 2100. The effect of temperature increase and accelerated melting is of primary importance, with enhanced evapotranspiration directly caused by warmer conditions playing a major role in runoff evolution. The impact of climate change and glacier mass loss on

the hydrology in the Mont-Blanc massif is expected to lead to a decrease in annual river discharge by 2100(Deacu et al., 2012; U.S. Global Change Research Program, 2018).

Climate-induced shifts in precipitation and glacial melt have led to significant changes in hydrochemistry, impacting water resources and quality. These changes include reduced dry-season water availability, influenced by decreasing snow cover and glacier mass loss, and changes in the location and amount of precipitation affecting water availability and quality. Glacial melt has also impacted stream hydrochemistry, with runoff being rich in fine sediment, affecting the stream hydrochemistry of headwater catchments. Additionally, changes in water pH due to climate-induced shifts can influence the availability of metals and other water quality parameters, impacting the overall quality of ground and surface water systems. These findings underscore the complex and multifaceted impacts of climate-induced shifts in precipitation and glacial melt on water resources and hydrochemistry, emphasizing the need for comprehensive monitoring and adaptive water resource management strategies (Barkdull et al., 2021; Castellazzi et al., 2019; Du et al., 2022; Yapiyev et al., 2021).

Chemistry of Adaptation and Mitigation Strategies

The chemical aspects of climate change adaptation and mitigation efforts in Afghanistan are crucial due to the country's vulnerability to climate change. Afghanistan's climate change projections highlight the need for robust data to inform adaptation and mitigation strategies. The country's arid and semi-arid climate, with cold winters and hot summers, presents unique challenges, particularly in the face of increasing temperatures and changes in precipitation patterns(Pa, 2009).

The following innovative technologies and practices have been identified to address climate-related challenges in Afghanistan:

1. **Adaptive Capacity Building:** Efforts have been made to build adaptive capacity at both the policy and practical levels, including working with local communities across four provinces to enhance resilience to climate change(Environment, 2016).
2. **Comprehensive Assessment and Planning:** The Afghanistan Vulnerability and Adaptation Technical Assessment Report aims to identify the main impacts of climate change on important sectors and propose priorities for adaptation action based on national strategies and plans(*Afghanistan Vulnerability and Adaptation Technical Assessment Report | UNEP - UN Environment Programme*, 2023; Snyman, 2020).
3. **Policy Development:** The Comprehensive Migration Policy (CMP) addresses the impacts of climate change, displacement, and migration, rectifying previous oversights and providing policy responses to these challenges(*Climate Change Compounds Longstanding Displacement in Afghanistan - Afghanistan | ReliefWeb*, 2023).
4. **Data Collection and Analysis:** The National Capacity Needs Self-Assessment for Global Environmental Management (NCSA) and the Climate Change Science Perspectives report provide valuable information for identifying key adaptation needs, potential adaptation options, and evaluation criteria(Environment, 2016).

These efforts reflect a multi-faceted approach to addressing climate-related challenges in Afghanistan, encompassing policy development, community engagement, and the collection and analysis of scientific data. By integrating chemical aspects into adaptation and mitigation strategies, Afghanistan is working to build resilience and reduce the impacts of climate change on its people and ecosystems.

Medicinal Plants and Biodiversity

The chemistry of medicinal plants native to Afghanistan and their resilience to changing climates is a topic of significant importance. Medicinal plants are fundamental to the health sovereignty of communities in Afghanistan, particularly in rural and remote areas. These plants are not only vital for healthcare but also serve as a source of livelihood. The diverse geo-climatic conditions of Afghanistan have led to high medicinal plant diversity, with hundreds of species traditionally utilized. However, the impact of climate change on the resilience of these plants is a growing concern, given the country's vulnerability to environmental changes. The chemistry of medicinal plants native to Afghanistan and their resilience to changing climates is a topic of significance. Afghanistan's diverse geo-climatic conditions have led to the utilization of a wide variety of medicinal plants, many of which are traditionally used in the region. These plants contain a range of chemical compounds that contribute to their medicinal properties. For instance, a study in the Badakhshan Province of northeastern Afghanistan identified 48 plants within 45 categories of treatment and prevention, with the greatest number of plants used to treat hypertension, kidney aids, and analgesics (Kassam et al., 2010).

The Impact of Climate Change On Biodiversity And Ecosystem Chemistry

The impact of climate change on biodiversity and ecosystem chemistry in Afghanistan is significant. The country has experienced an increase in drought, frequency of floods, and warmer temperatures, which have led to adverse effects on the environment and the diversity of plant species. The changing climate has the potential to alter the chemical composition of ecosystems, affecting the growth and survival of medicinal plants. This, in turn, can have implications for the availability and quality of traditional medicinal resources. Additionally, over 215 plants used in traditional therapy in Afghanistan contain essential oils, with families such as Lamiaceae, Asteraceae, and Apiaceae being widely found and utilized(Nazifa Faqeryar & Yoshihito Mori, 2018; Sanaei et al., 2023).

The impact of climate change on biodiversity and ecosystem chemistry in Afghanistan is also a matter of concern. The changing climate can affect the distribution, abundance, and chemical composition of medicinal plants, potentially influencing their resilience. Furthermore, climate change can lead to shifts in the availability of certain plant species, impacting the traditional uses of these plants and the chemical compounds they contain. This can have implications for the health sovereignty of local communities that rely on these medicinal plants for healthcare and livelihood options. The ability to preserve medicinal plants through periods of instability, unusual growing seasons, and changing climatic conditions is essential for maintaining health sovereignty(Kassam et al., 2010).

Innovative technologies and practices aimed at addressing climate-related challenges in Afghanistan include the preservation and sustainable management of medicinal plants. Efforts to conserve indigenous knowledge and promote sustainable harvesting practices are essential for ensuring the resilience of medicinal plants to changing climates. Additionally, the development of climate-resilient agricultural practices and the implementation of policies to address the impacts of climate change on biodiversity are crucial for the preservation of medicinal plant resources.

Challenges And Future Directions

Afghanistan faces significant challenges in addressing climate change from a chemical perspective. The country is among the world's most vulnerable to climate change, with serious impacts on its people and ecosystems. The impact of climate change on biodiversity and ecosystem chemistry is significant, with adverse effects on the environment and the diversity of plant species. The changing climate has the potential to alter the chemical composition of ecosystems, affecting the growth and survival of medicinal plants, which are fundamental to the health sovereignty of communities in Afghanistan.

The lack of scientifically robust climate data in Afghanistan is a significant challenge, making it difficult to develop effective policies and strategies to address climate change. The country's limited research on climate change and flooding trends is another challenge, highlighting the need for more research in this area. Additionally, the lack of resources and capacity to cope with the impacts of climate change is a significant challenge, with national budgets primarily focused on combatting security challenges.

Conclusion

The findings of this review emphasize the urgent need for action to address the impacts of climate change in Afghanistan. The review has highlighted that Afghanistan is among the world's most vulnerable countries to climate change, with serious impacts on its people and ecosystems. The lack of scientifically robust climate data in Afghanistan is a significant challenge, making it difficult to develop effective policies and strategies to address climate change. The country's limited research on climate change and flooding trends is another challenge, highlighting the need for more research in this area. Additionally, the lack of resources and capacity to cope with the impacts of climate change is a significant challenge, with national budgets primarily focused on combatting security challenges. Future research and policy efforts should focus on developing effective strategies to address these challenges and preserve the country's biodiversity and ecosystem chemistry. The findings underscore the importance of chemistry in understanding and addressing climate change, and the need for innovative technologies and practices aimed at preserving and sustainably managing natural resources. The review provides valuable insights into the challenges and opportunities for addressing climate change in Afghanistan and can serve as a basis for future research and policy efforts.

References

1 Afghanistan- Climatology | Climate Change Knowledge Portal (2023). https://climateknowledgeportal.worldbank.org/country/afghanistan/climate-data-historical
2 Afghanistan Air Quality Index (AQI) and Air Pollution information | IQAir. (2024). https://www.iqair.com/us/afghanistan
3 Afghanistan Vulnerability and Adaptation Technical Assessment Report | UNEP - UN Environment Programme. (2023). https://www.unep.org/resources/assessment/afghanistan-vulnerability-and-adaptation-technical-assessment-report
4 Afghanistan: The alarming effects of climate change | OCHA. (2023). https://www.unocha.org/news/afghanistan-alarming-effects-climate-change
5 Aich, V.,& Khoshbeen, A. J. (2023). Afghanistan: Climate Change Science Perspectives. Kabul: National Environmental Protection Agency (NEPA) and UN Environment. https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health
6 Barkdull, N. S., Carling, G. T., Fernandez, D. P., Nelson, S. T., Bickmore, B. R., Tingey, D. G., Checketts, H. N., Packer, B. N., & Hale, C. A. (2021). Glaciers Control the Hydrogeochemistry of Proglacial Streams During Late Summer in the Wind River Range, Wyoming, United States. Frontiers in Earth Science, 9(October), 1–15. https://doi.org/10.3389/feart.2021.727575
7 Brevik, E. C. (2013). The potential impact of climate change on soil properties and processes and corresponding influence on food security. Agriculture, 3(3), 398–417.https://doi.org/10.3390/agriculture3030398
8 Castellazzi, P., Burgess, D., Rivera, A., Huang, J., Longuevergne, L., & Demuth, M. N. (2019). Glacial Melt and Potential Impacts on Water Resources in the Canadian Rocky Mountains. Water Resources Research, 55(12), 10191–10217. https://doi.org/10.1029/2018WR024295
9 Chapter 4: Water | Climate Change 2022: Impacts, Adaptation and Vulnerability. (n.d.). Retrieved January 1, 2024, from https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-4/
10 Climate Change Compounds Longstanding Displacement in Afghanistan - Afghanistan | ReliefWeb. (2023). https://reliefweb.int/report/afghanistan/climate-change-compounds-longstanding-displacement-afghanistan
11 Climate Change Impacts on Agriculture and Food Supply | US EPA. (2023). https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply
12 Deacu, D., Fortin, V., Klyszejko, E., Spence, C., &Blanken, P. D. (2012). Predicting the net basin supply to the Great Lakes with a hydrometeorological model. Journal of Hydrometeorology, 13(6), 1739–1759. https://doi.org/10.1175/JHM-D-11-0151.1
13 Du, X., Silwal, G., &Faramarzi, M. (2022). Investigating the impacts of glacier melt on stream temperature in a cold-region watershed: Coupling a glacier melt model with a hydrological model. Journal of Hydrology, 605, 127303. https://doi.org/10.1016/J.JHYDROL.2021.127303
14 Environment, N. & U. (2016). Afghanistan: Climate Change Science Perspectives. 34. https://www.weadapt.org/sites/weadapt.org/files/afghanistan_climate_change_science_perspective_0.pdf
15 Food & Soil Health | Soil and Environmental Biogeochemistry. (2023). https://soil.sites.stanford.edu/research/food-soil-health
16 Gasping for air in Kabul. (2023). https://www.unep.org/news-and-stories/story/gasping-air-kabul
17 Hamidov, A., Helming, K., Bellocchi, G., Bojar, W., Dalgaard, T., Ghaley, B. B., Hoffmann, C., Holman, I., Holzkämper, A., &Krzeminska, D. (2018). Impacts of climate change adaptation options on soil functions: A review of European case-studies. Land Degradation & Development, 29(8), 2378–2389.
18 How air pollution affects our health. (2023). https://www.eea.europa.eu/en/topics/in-depth/air-pollution/eow-it-affects-our-health
19 Jawadi, H. A., Sagin, J., & Snow, D. D. (2020). A Detailed Assessment of Groundwater Quality in Kabul Basin. Water, 1–19.
20 Jawid, A., &Khadjavi, M. (2019). Adaptation to climate change in Afghanistan: Evidence on the impact of external interventions. Economic Analysis and Policy, 64, 64–82.
21 Kassam, K. A., Karamkhudoeva, M., Ruelle, M., &Baumflek, M. (2010). Medicinal Plant Use and Health Sovereignty: Findings from the Tajik and Afghan Pamirs. Human Ecology, 38(6), 817. https://doi.org/10.1007/S10745-010-9356-9
22 Manisalidis, I., Stavropoulou, E., Stavropoulos, A., &Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. Frontiers in Public Health, 8, 14.
23 National Institute of Environmental Health Sciences: Air Pollution and Your Health. (2023). https://www.niehs.nih.gov/health/topics/agents/air-pollution

24 NazifaFaqeryar, & Yoshihito Mori. (2018). Extraction of Essential Oils from Afghanistan Medicinal Plants Using Microwave and Conventional Methods. Journal of Pharmacy and Pharmacology, 6(3), 202–216. https://doi.org/10.17265/2328-2150/2018.03.002
25 Pa, N. E. (2009). Afghanistan NationalNational Capacity Needs Self-Assessment for Global Environmental Management (NCSA) and National Adaptation Programme of Action for Climate Change (NAPA) (Issue February). https://www4.unfccc.int/sites/NAPC/Country Documents/Parties/napa-afghanistan-final.pdf
26 Pareek, N. (2017). Climate change impact on soils: adaptation and mitigation. MOJ Ecol. Environ. Sci, 2, 136–139.
27 Parikh, S. J., & James, B. R. (2012). Soil: the foundation of agriculture. Nature Education Knowledge, 3(10), 2.
28 Patrick, D. L. (2016). Health and Environmental Effects of Air Pollution. Health & Environmental Effects of Air Pollution Health, 1–3. http://www.epa.gov/globalwarming/.
29 Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., Zhou, L., Liu, H., Ma, Y., & Ding, Y. (2010). The impacts of climate change on water resources and agriculture in China. Nature, 467(7311), 43–51.
30 Pozza, L. E., & Field, D. J. (2020). The science of soil security and food security. Soil Security, 1, 100002.
31 Rana, J., Uddin, J., Peltier, R., &Oulhote, Y. (2019). Associations between indoor air pollution and acute respiratory infections among under-five children in afghanistan: Do SES and sex matter? International Journal of Environmental Research and Public Health, 16(16). https://doi.org/10.3390/ijerph16162910
32 Reimagining the Role of Chemistry in Food Security - American Chemical Society. (2023). https://www.acs.org/sustainability/summits/zero-hunger/speakers/reimagining-the-role-of-chemistry-in-food-security.html
33 Saalidong, B. M., Aram, S. A., Otu, S., & Lartey, P. O. (2022). Examining the dynamics of the relationship between water pH and other water quality parameters in ground and surface water systems. PloS One, 17(1), e0262117. https://doi.org/10.1371/journal.pone.0262117
34 Safi, L., Mujeeb, M., Sahak, K., Mushwani, H., & Hashmi, S. K. (2024). Climate change impacts and threats on basic livelihood resources, food security and social stability in Afghanistan. GeoJournal, 89(2), 85. https://doi.org/10.1007/s10708-024-11077-8
35 Sanaei, A., Herrmann, H., Alshaabi, L., Beck, J., Ferlian, O., Fomba, K. W., Haferkorn, S., van Pinxteren, M., Quaas, J., Quosh, J., Rabe, R., Wirth, C., Eisenhauer, N., &Weigelt, A. (2023). Changes in biodiversity impact atmospheric chemistry and climate through plant volatiles and particles. Communications Earth & Environment, 4(1), 445. https://doi.org/10.1038/s43247-023-01113-9
36 Sayed, N., & Sadat, S. H. (2022). Climate change compounds longstanding displacement in Afghanistan. Migration Policy Institute.
37 Snyman, D. (2020). Vulnerability and adaptation - Technical assessment report. https://www.unep.org/resources/assessment/afghanistan-vulnerability-and-adaptation-technical-assessment-report
38 Sundem, L. (2014). Quality of drinking water in Afghanistan. 46.
39 The Effect of Climate Change on Water Resources and Programs | Watershed Academy Web | US EPA. (2023). https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2469
40 The slow violence of pollution in Afghanistan - CEOBS. (2018). https://ceobs.org/the-slow-violence-of-pollution-in-afghanistan/
41 U.S. Global Change Research Program. (2018). Climate science special report: Fourth national climate assessment, volume I. U.S. Global Change Research Program, 1, 470. https://doi.org/10.7930/J0J964J6
42 Ullah, A., Bano, A., & Khan, N. (2021). Climate change and salinity effects on crops and chemical communication between plants and plant growth-promoting microorganisms under stress. Frontiers in Sustainable Food Systems, 5(June), 618092. https://doi.org/10.3389/fsufs.2021.618092
43 Water quality and quantity are key for well-being. (2023). https://www.eea.europa.eu/en/newsroom/editorial/water-quality-and-quantity
44 WBG, & ADB. (2021). Afghanistan Climate Risk Country Profile. www.worldbank.org
45 WFP, UNEP, & NEPA. (2016). Climate Change in Afghanistan. UNEP World Food Program NEPA.
46 Yapiyev, V., Wade, A. J., Shahgedanova, M., Saidaliyeva, Z., Madibekov, A., &Severskiy, I. (2021). The hydrochemistry and water quality of glacierized catchments in Central Asia: A review of the current status and anticipated change. Journal of Hydrology: Regional Studies, 38 (November), 100960. https://doi.org/10.1016/j.ejrh.2021.100960
47 Lee, Y. J., Kim, N. S., Kim, H., Yi, J. M., Oh, S. M., Bang, O. S., & Lee, J. (2013). Cytotoxic and anti-inflammatory constituents from the seeds of Descurainia sophia. *Archives of Pharmacal Research*, *36*(5), 536–541. https://doi.org/10.1007/s12272-013-0066-x