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Anticipating Climate Catastrophe: The Impacts of Diminished Snowfall in Gilgit-Baltistan and Azad Jammu & Kashmir

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Abstract
Climate change poses a significant threat to regions like Azad Jammu & Kashmir (AJ&K) and Gilgit-Baltistan (GB), where vulnerabilities are pronounced. Decreased snowfall alters water supplies and agriculture, exacerbating climate-related challenges. Integrated strategies, drawing on research, policy, and community efforts, are crucial for addressing these impacts effectively. Scientists agree on human-induced global warming, impacting precipitation patterns, temperatures, and glaciers in GB and AJ&K. Such changes affect water availability, agriculture, and increase the frequency of severe weather events, endangering local livelihoods. Of particular concern is the accelerated melting of glaciers in the Hunza Basin, heightening the risk of Glacial Lake Outburst Floods (GLOFs) and posing a threat to downstream communities. Addressing climate change requires comprehensive approaches. This includes infrastructure resilience, community preparedness, sustainable agriculture, and improved early warning systems. Collaboration across sectors, investment in climate science, and empowering local communities are essential. Urgent action, at local, national, and global levels, is vital to mitigate climate change impacts and secure a sustainable future for all vulnerable regions like GB and AJ&K.
Keywords: Climate change, threat, Azad Jammu & Kashmir, Gilgit-Baltistan, challenges, efforts, Hunza Basin, Glacial Lake Outburst Floods, comprehensive approaches, sustainable future

1. Introduction to Climate Change

Climatic change is a profound and complex modification of the Earth's climate system. Temperature, precipitation patterns, and the frequency and intensity of extreme weather events all change over time. Human activities are the primary driver of climate change, particularly the emission of greenhouse gases (GHGs) such as methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O). These gas emissions contribute to the greenhouse effect, which causes an increase in the Earth's average temperature, a process known as global warming. The evidence of human effect on the climate system is unequivocal, with significant studies indicating the acceleration of climate change caused by anthropogenic activity since the industrial revolution (The Scientific Consensus on Climate Change, 2004).

The scientific consensus, as represented by the Intergovernmental Panel about Climate Change(IPCC), suggests that the impacts of climate change are widespread, reaching every corner of the globe and affecting natural and human systems in profound ways (IPCC, 2014). The implications of these changes are far-reaching, affecting water resources, agricultural productivity, ocean acidity, and leading to the loss of biodiversity. Furthermore, the increased frequency and intensity of extreme climate changes, such as hurricanes, floods, and droughts, pose substantial threats to human health, safety, and livelihoods (Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012).

Recent studies underscore the need of addressing climate change. Study provide an analysis of global surface temperature change, highlighting the rapid warming observed in recent decades. Their research emphasizes the critical need for concerted global action to mitigate greenhouse gas emissions and adapt to unavoidable impacts. Similarly, scientists examine the impacts of climate change on natural and human systems, detailing how vulnerabilities and exposure to climate-related risks are increasing globally (Hansen, Ruedy, Sato, & Lo, 2010).

1.1. Definition and Significance of Climate Change

The definition of climate change, as articulated by the Intergovernmental Panel about Climate Change (IPCC), underscores the profound and enduring alterations in the climate system. This encompasses not just changes in average temperatures but also shifts in the distribution and severity of weather events and natural phenomena. The significance of climate change is monumental, touching virtually all facets of the Earth's environment and human society. It transforms weather patterns, elevates sea levels, intensifies the frequency and severity of extreme weather conditions, and exerts considerable impacts on natural ecosystems, agricultural productivity, freshwater supplies, and overall human health and welfare.

The broad-reaching effects of climate change are documented extensively in scientific literature, highlighting the urgent need for comprehensive understanding and action. For instance, a study on the increasing rate of global temperature rise provides compelling evidence of accelerated climate change over the past few decades, primarily due to anthropogenic emissions (Climate sensitivity, sea level and atmospheric carbon dioxide, 2013).

Another critical piece of research, examines the repercussions of climate change on ocean ecosystems, revealing significant effects on coastal ecosystems, fisheries, and carbon sequestration in the world's oceans (Brown, 2015).

These studies, among others, contribute to the growing body of evidence emphasizing the wide-ranging implications of climate change. They call for urgent mitigation and adaptation strategies to safeguard inherentecosystems, ensure water and food security, and protect human livelihoods and health against the advancing threats of climate change.

1.2. Global Climate Change Overview (International/World Perspective)

Globally, climate change has led to observable alterations in the environment. Since the late nineteenth century, the average surface temperature has increased by roughly 1.1 degrees Celsius, owing primarily to rising carbon dioxide and other human-caused emissions into the atmosphere.The past decade (2010-2019) was the warmest on record, highlighting a clear trend of escalating global temperatures (NASA, 2020).

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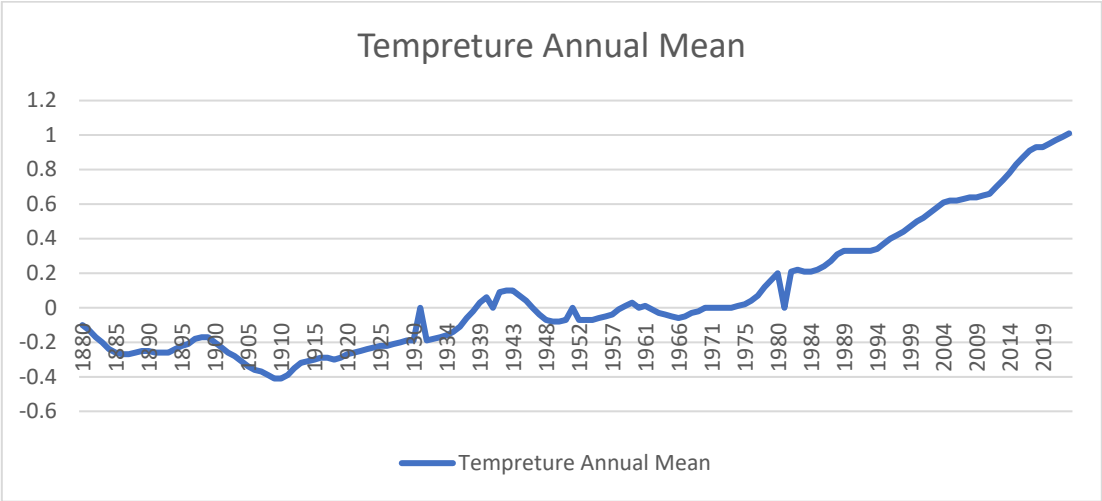


Moreover, the impacts of climate change are not uniform across the globe. Some regions experience more severe weather patterns, including increased rainfall, while others face droughts and diminished snowfall. The Arctic, for example, is warming twice as quickly as the rest of the planet, resulting in the rapid melting of ice and snow, with global ramifications for sea level rise and climatic patterns (NOAA, 2019).

In regions like Gilgit-Baltistan and Azad Jammu & Kashmir, the effects of climate change are particularly pronounced in the form of diminished snowfall. These areas, crucial for their water resources originating from glacial melt, are witnessing significant shifts in precipitation patterns and glacial retreat. A study by the Pakistan Meteorological Department (PMD) and research conducted by global climate scientists highlight that the rate of glacier melt in these regions has accelerated in recent years, posing serious concerns for water availability, agriculture, and livelihoods in downstream areas (Assessment of glacier status and its controlling parameters from 1990 to 2018 of Hunza Basin, Western Karakorum, 2021) .

Table 1

Year 2000	Batura Glacier	Hispar Glacier	Khurdopin Glacier	Momhil Glacier	Mulungutti Glacier	Virjerab Glacier	Yazgil Glacier
14	56.14	11.03	31.43	23.80	37.34	24.62	35.16
15	98.26	63.79	65.00	55.89	58.44	60.69	68.23
16	66.32	46.27	39.39	59.74	59.41	49.92	42.83
17	15.84	77.40	87.24	80.00	89.90	84.89	101.25

Annual average glacier velocities (myr-1) in the Hunza Basin during 2014 – 2017.

The diminished snowfall in Gilgit-Baltistan and Azad Jammu & Kashmir not only affects water resources but also has broader implications for climate-induced disasters such as floods and droughts. Reduced snowfall alters the hydrological cycle, leading to changes in river flow patterns and timing, which can exacerbate the risk of both floods during heavy rain events and droughts during dry periods (Modeling the response of the langtang glacier and the hintereisferner to a changing climate since the little ice age, 2019).

2. Regional Focus: GB & AJ&K Climate Change

2.1. Historical Climate Patterns of AJK / GB (Last 10-15 years)

Over the last 10 to 15 years, the regions of Azad Jammu & Kashmir (AJ&K) and Gilgit-Baltistan (GB) have experienced marked changes in their climate, significantly deviating from their historical weather patterns. These areas, known for their distinct seasons—characterized by predictable snowfall in winter and moderate summers—have seen trends towards warmer temperatures, reduced snowfall, and irregular precipitation patterns. These shifts are not just anomalies but indicators of the broader effects of climate change, profoundly affecting the region's hydrology, water availability, and thereby, the livelihoods of its inhabitants.

2.2. Temperature Increases and Precipitation Patterns

2.2.1. Temperature Trends

The increase in average temperatures across GB and AJ&K is a significant indicator of climate change in these regions. Research confirms this trend, showing a consistent rise in temperatures, which has contributed to the accelerated melting of glaciers. Such temperature increases have direct implications for water resources, agriculture, and biodiversity in the region (Streamflow response to projected climate changes in the Northwestern Upper Indus Basin based on regional climate model (RegCM4.3) simulation, 2019).

2.3. Precipitation Variability

Alongside rising temperatures, there has been a noticeable shift in precipitation patterns. Study highlight the increasing unpredictability of rainfall, with a shift towards more erratic and extreme weather events. This variability in precipitation has led to challenges in water management, agriculture, and disaster preparedness, further emphasizing the need for adaptive strategies in answer to climate change (The history of rainfall data time-resolution in a wide variety of geographical areas, 2020).

Table 2

Area	Season	Average Precipitation	Std. Dev.	Range Precipitation Min	Range Precipitation Max
GB	Winter	94	63	19	214
GB	Spring	74	35	7	250
GB	Summer	52	15	6	148
GB	Autumn	17	11	0.1	128

This show the precipitation in different sessions in mm.

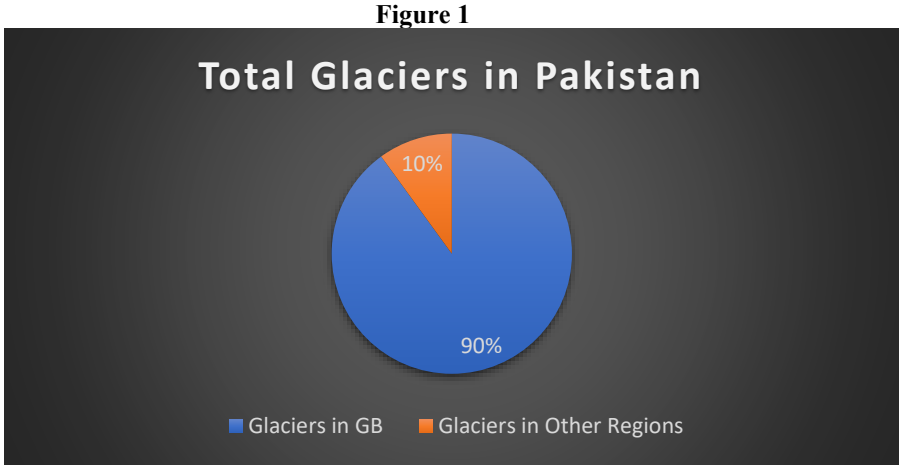
2.4. Effects on Glaciers and Water Resources

The glaciers in GB and AJ&K serve as critical water reserves, feeding into the Indus Basin and supporting millions of people in downstream areas. The rapid melting of these glaciers, exacerbated by increased temperatures, poses a risk not only to water availability but also leads to the creation of glacial lakes, which can result in Glacial Lake Outburst Floods (GLOFs). Hasson investigated the effect of climate change on these glacial behaviors, noting the increased frequency and intensity of GLOFs, which threaten infrastructure, livelihoods, and ecosystems (Hydrological cycle over South and Southeast Asian river basins as simulated by PCMDI/CMIP3 experiments, 2013).

2.5. Socioeconomic Implications

The climatic shifts observed in GB and AJ&K have profound socioeconomic implications. The region's agriculture, heavily reliant on predictable seasonal patterns, faces uncertainty due to changing water availability and the increased risk of floods and droughts. This unpredictability affects food security, income generation, and the overall economic stability of communities in these regions.

Figure 1



2.6. Observed Climate Change in GB & AJ&K

The observed climate change in Azad Jammu & Kashmir (AJ&K) and Gilgit-Baltistan (GB) over recent years is a vivid illustration of the broader impacts of global warming on specific regions. Research within these areas has consistently documented a rise in temperature, signaling a clear warming trend that is having profound effects on the environment and the communities living in these regions. This warming is contributing to the accelerated melting of glaciers, which are a pivotal water source for the rivers flowing through these areas. Additionally, precipitation patterns have become increasingly erratic, leading to a rise in severe weather events, such as heavy rainfall resulting in floods and landslides.

2.7. Temperature Trends and Glacial Melt

The rise in average annual temperatures in GB and AJ&K is a significant indicator of climate change, with direct implications for the region's glacial reserves. Glaciers, crucial for their role in feeding the river systems of the Indus Basin, are retreating at alarming rates. The meltwater from these glaciers supports agriculture, hydropower generation, and the livelihoods of millions downstream during the dry season. As temperatures continue to rise, the accelerated melting of these glaciers poses a serious threat to water security in the region.

Table 3

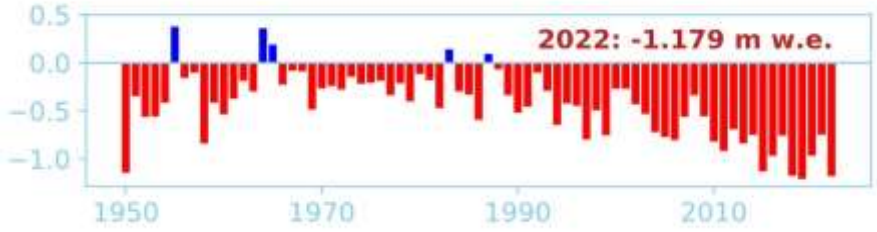
Lake Type	Number	Length (km)	Area (ha)	Largest Lake (ha)	Smallest Lake (ha)
Cirque	15	6.45	251.37	103.66	0.79
End Moraine	8	3.6	128.38	71.32	1.43
Erosion	40	7.54	115.31	11.86	0.38
Lateral Moraine	7	1.15	10.37	2.71	0.79
Valley	5	1.48	35.87	30.44	0.72
Block	1	0.24	3.76	3.76	3.76
Total	76	20.44	545.04	223.74	7.87

Summary of the many kinds of glacial lakes in AJK.

A study explores the effects of climate change on the cryosphere of the Himalayan region, including GB and AJ&K, highlights the vulnerability of these glaciers to rising temperatures. The research points out that the rate of glacier retreat has intensified over the past decade, directly correlating with the observed increase in temperatures. This rapid glacial melt contributes to the formation of

glacial lakes, raising the hazard of Glacial Lake Outburst Floods (GLOFs), which have devastating consequences for downstream communities (Climate change, cryosphere and impacts in the Indian Himalayan Region, 2021).

Figure 2



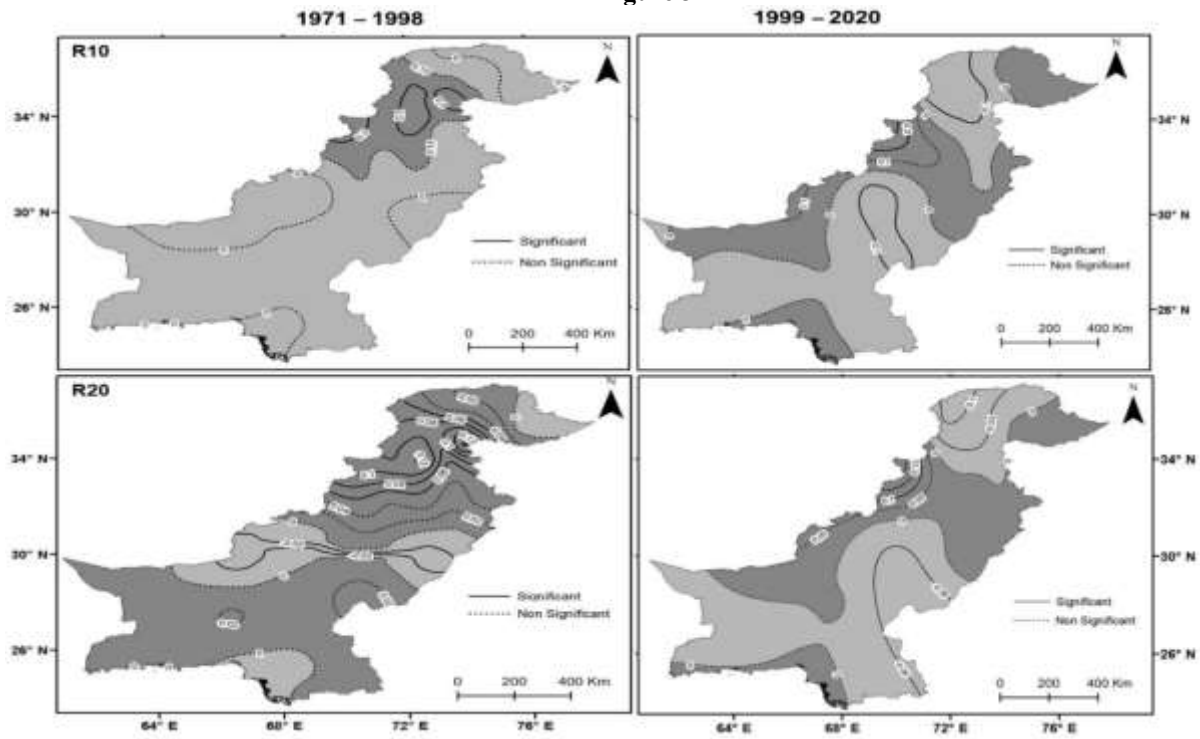
Source: World Glacier Monitoring Service (WGMS)

2.8. Precipitation Variability and Extreme Weather Events

The erratic nature of precipitation patterns in GB and AJ&K is another critical aspect of the observed climate change in these areass. The shift towards more unpredictable and extreme precipitation events has led to increased incidences of floods and landslides, posing significant risks to human life, infrastructure, and agriculture. The unpredictability of these patterns complicates water management and agricultural planning, making it challenging for communities to adapt to the changing climate.

Research on altering precipitation patterns in the upper Indus basin reveals an increasing tendency of extreme weather occurrences. The study observes a considerable increase in the intensity and frequency of heavy rainfall events over the last decade, resulting in increased flood risks and heightened susceptibility for communities in GB and AJ&K. These findings underscore the need for improved climate resilience and adaptation strategies in these mountainous regions, where the impacts of climate change are particularly pronounced (The history of rainfall data time-resolution in a wide variety of geographical areas, 2020).

Figure 3



Spatial trends for the extreme precipitation indices R10 and R20 (days) from 1971 to 1998, as well as 1999 to 2020. At the 0.05 level of significance, dark colour denotes positive changes, whereas light colour indicates negative changes. (Abbas et al., 2023)

The socioeconomic implications of these climatic changes are profound. The livelihoods of the people in GB and AJ&K, many of whom depend on agriculture and livestock, are increasingly threatened by the changing climate. The erratic precipitation and the threat of GLOFs disrupt agricultural cycles and water availability, leading to food insecurity and economic instability. Furthermore, the increased frequency of landslides and floods not only endangers lives but also damages critical infrastructure, further exacerbating the region's vulnerability to climate change.

2.9. Nature of Climatic Hazards Specific to GB & AJ&K

The regions of Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K) face unique climatic hazards that are being intensified by the changing climate. These hazards not only pose immediate risks to the populations residing in these areas but also threaten long-term sustainability and development.

2.10. Glacial Lake Outburst Floods (GLOFs)

One of the most catastrophic hazards in GB and AJ&K is Glacial Lake Outburst Floods (GLOFs). These events occur when the dams holding back glacial lakes fail, releasing massive quantities of water downstream. The rapid melting of glaciers, a direct result of rising global temperatures, aids in the creation and expansion of these glacial lakes. The Himalayan region has seen a rise in the frequency and size of GLOFs, which is attributed to climate change-induced glacial retreat. The research emphasizes the need for enhanced monitoring and early warning systems to mitigate the impact of GLOFs on vulnerable communities (Increasing risk of glacial lake outburst floods from future Third Pole deglaciation, 2021).

Table 4

Date	Glaciers	Rivers
29-07-1994	Sosot/Gupis	Gilgit
06-08-1999	Khalti/Gupis	Gilgit
10-06-2000	Shimshal	Indus
27-08-2000	Kand/Hushe	Indus
25-07-2005	Sosot/Gupis	Gilgit
05-04-2007	Ghulkin	Hunza
06-01-2008	Passu	Hunza
22-04-2008	Ghulkin	Hunza
22-05-2008	Ghulkin	Hunza
24-05-2008	Ghulkin	Hunza
14/15-06-2008	Ghulkin	Hunza
26-03-2009	Ghulkin	Hunza
08-07-2012	Sosot/Gupis	Hunza

Historical GLOF incidents in Gilgit-Baltistan. (Source, NARC 2008, Archer 2001, UNDP 2007, Pamir Times June 2008. FOCUS, 2012)

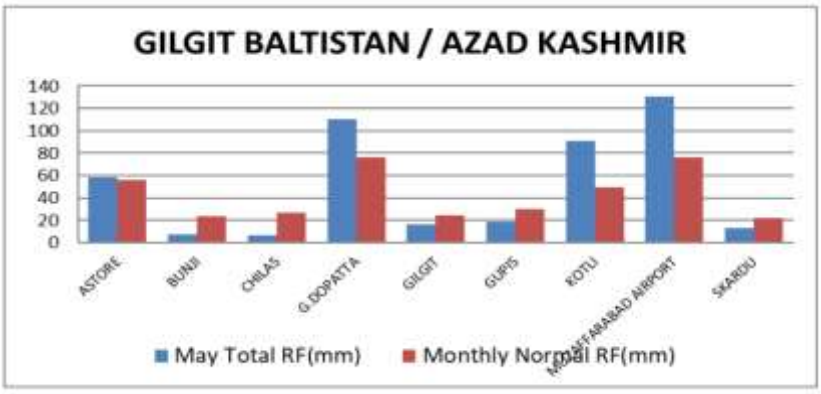
2.11. Landslides and Soil Erosion

Increased precipitation intensity, alongside deforestation and land use changes, exacerbates the risk of landslides and soil erosion in GB and AJ&K. These processes not only damage the environment but also have significant implications for agriculture and infrastructure. The destabilization of slopes due to heavy rainfall, often occurring in areas where vegetation has been cleared, leads to increased landslide occurrences. Analysis on the impact of precipitation patterns on landslide frequency in the region underscores the correlation between changing climate conditions and heightened landslide risks. The study calls for integrated land management and reforestation efforts to reduce vulnerability (Impacts of Climate Change on Biodiversity in Pakistan: Current Challenges and Policy Recommendations, 2022).

2.12. Droughts

Contrasting with the increase in extreme precipitation events, periods of low rainfall are becoming more common in GB and AJ&K, leading to drought conditions that affect the water supply for drinking, irrigation, and hydropower generation. This paradoxical situation highlights the complex impacts of climate change, where increased variability in weather patterns leads to both floods and droughts. Research on the hydrological effects of climate change in the Indus River Basin reveals that drought frequency and severity are on the rise, impacting water availability for millions dependent on this critical water source. The study emphasizes the importance of adaptive water management strategies to cope with the changing climate (Impacts of climate change on thewater availability, seasonality and extremes in the Upper Indus Basin (UIB), 2020).

Figure 4



Monthly Normal to Actual Rainfall Comparison for May-2023 Source: Pakistan Meteorological Department

Addressing the climatic hazards in GB and AJ&K requires an integrated approach that combines local knowledge with scientific research. Building resilience against these hazards involves enhancing early warning systems, implementing sustainable land management practices, and developing adaptive water management strategies to ensure the availability of water for all uses.

3. Impact Assessment

3.1. Progressive Changes of Climate in the Last Decade

Over the last decade, the Earth's climate system has undergone significant transformations, with marked shifts in weather patterns, temperature norms, and precipitation patterns becoming increasingly evident across the globe. These changes are predominantly attributed to a continuous increase in greenhouse gas emissions, which have accelerated the pace of global warming and climatic shifts. The implications of these changes are profound, affecting ecosystems, human health, agricultural productivity, and water security worldwide.

3.2. Temperature Rise

The worldwide average temperature has experienced a notable increase, making the past decade the warmest on record. As per the Intergovernmental Panel on Climate Change (IPCC), the globally averaged temperature has risen by about 1.0 degrees Celsius above pre-industrial levels. This warming trend has pushed ecosystems and communities beyond their capacity to adapt, threatening biodiversity and increasing the risk of food and water scarcity (Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming, 2018).

Further studies have explored the ramifications of this temperature rise, highlighting the accelerated melting of the polar ice caps and the resulting rise in sea levels. These changes pose a significant threat to coastal communities and contribute to the increasing frequency of heatwaves, impacting human health and productivity.

3.3. Precipitation Patterns

The last decade has also seen significant changes in precipitation patterns, with some regions experiencing more frequent and intense rainfall events, while others endure prolonged periods of drought. Hansen have documented these shifts, noting their significant implications for water security, agricultural productivity, and biodiversity. The variability in rainfall affects soil moisture levels, river flows, and groundwater recharge rates, leading to challenges in water management and agricultural planning (Atmospheric Chemistry and Physics Earth's energy imbalance and implications, 2011).

Recent research provides insights into how these altered precipitation patterns contribute to severe droughts and floods. The study illustrates the complex interplay between climate change and the hydrological cycle, underscoring the need for adaptive water management strategies to mitigate these impacts (Climate Change Impact on the Streamflow for the Nam Ou Catchment, North Laos in the Mekong Basin, 2023).

3.4. Extreme Weather Events

The escalation of severe weather incidents, including hurricanes, wildfires, heatwaves, and floods, underscores a critical aspect of climate change's broad-reaching impacts. This phenomenon, exacerbated by human activities that contribute to global warming, presents profound challenges to environmental stability, economic development, and human safety. In regions such as Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K), the consequences of such events are particularly acute, given the areas' vulnerability to climate-induced disasters, which are compounded by reduced snowfall affecting water availability and agricultural productivity.

The growing frequency and intensity of severe weather events have been well documented, with extensive research pointing to their negative effects on natural and human systems. The National Climate Assessment emphasizes that these events are not only becoming more common but also more devastating, impacting economies, ecosystems, and communities. For GB and AJ&K, the implications are manifold, affecting water resources, food security, and the overall well-being of the populations (Impacts of climate warming and habitat loss on extinctions at species' low-latitude range boundaries, 2006).

A detailed examination of the economic and policy ramifications of extreme weather events. They argue for the necessity of integrated climate policies that tackle greenhouse gas emissions while simultaneously bolstering community resilience against such events. Their analysis highlights the dual approach required in addressing the root causes of climate change and mitigating its most immediate and destructive effects (A. N. Khan, 2010).

In GB and AJ&K, the impacts of extreme weather events are exacerbated by the regions' geographical and climatic characteristics. Reduced snowfall leads to diminished water supplies, crucial for agriculture, drinking, and hydropower generation, thereby increasing vulnerability to droughts and heatwaves. Simultaneously, erratic precipitation patterns heighten the risk of floods, landslides, and other hydro-meteorological hazards, threatening lives, livelihoods, and infrastructure.

3.5. Current Climate Changes

In more recent years, the pace of climate change has not slowed, with many regions experiencing even more pronounced effects.

3.6. Accelerated Glacial Melt

Recent years have seen a significant acceleration in the rate of glacial melt worldwide. This rapid decline in ice mass is not only a stark indicator of rising global temperatures but also contributes to sea-level rise, threatening coastal communities and ecosystems. Glaciers, serving as crucial freshwater reservoirs, support billions of people globally. Their retreat jeopardizes water supplies, impacting agricultural production, drinking water availability, and hydroelectric power generation.

A notable study examines the global glacier mass balance and highlights the stark acceleration in glacial melt rates over the past decade. This research underscores the urgent need for strategies to mitigate the effects of climate change on glacial retreat and its broader implications for sea-level rise and water security (Twentieth-century global-mean sea level rise: Is the whole greater than the sum of the parts?, 2013).

3.7. Ocean Warming and Acidification

The oceans have absorbed a significant portion of the increased heat resulting from greenhouse gas emissions, leading to widespread ocean warming. This warming is accompanied by acidification, a result of the oceans absorbing CO2 from the atmosphere. The combination of these elements presents serious dangers to marine ecosystems, particularly coral reefs, which are extremely susceptible to changes in temperature and acidity.

In their comprehensive analysis, detail the impacts of ocean warming and acidification on marine biodiversity. Their findings highlight the profound effects on coral reefs, fish populations, and the services these ecosystems provide to human societies,

emphasizing the interconnectedness of ocean health and human well-being (The resilience of marine ecosystems to climatic disturbances, 2017).

3.8. Biodiversity Loss

The impact of climate change on global biodiversity has been profound, with habitat destruction, overexploitation, and climate change acting synergistically to drive species loss at unprecedented rates. The alteration of natural habitats due to changing climate conditions, alongside direct human impacts, has placed immense pressure on wildlife, leading to a significant loss of biodiversity.

Table 5

Ecosystem	Characteristics	Significance	Threats
Indus Delta and Coastal Wetlands	Mangroves, mudflats, limited protection	Diverse avian/marine life, turtle habitat	Freshwater flow reduction, mangrove cutting, wetland drainage
Indus River and Wetlands	Wetlands	Migratory flyway, Indus dolphin habitat	Water diversion, agriculture, pollution
Chagai Desert	Ancient desert	Endemic species	Mining, hunting
Balochistan Juniper Forest	Ancient junipers	Largest juniper forest, unique biodiversity	Fuelwood cutting, overgrazing, fragmentation
Chilghoza Forest (Suleiman Range)	Mountain soils, rock outcrops	Wildlife habitat for at-risk species	Fuelwood cutting, overgrazing, illegal hunting
Balochistan Subtropical Forests	Mid-altitude, sparse canopy	Important wildlife habitat, rich flora	Fuelwood cutting, overgrazing
Balochistan Rivers	Isolated from Indus River	Unique aquatic biodiversity, endemism	Water diversion, overfishing
Tropical Deciduous Forests	From Margalla Hills to Azad Kashmir	Floristically rich	Fuelwood cutting, overgrazing
Moist/Dry Temperate Himalayan Forests	Fragmented forests	Avian diversity hotspot, wildlife habitat	Logging, fuelwood cutting, overgrazing
Trans-Himalayan Alps and Plateaus	Mountain scenery	Unique flora/fauna, endemism	Fuelwood cutting, overgrazing, illegal hunting, unregulated tourism, fragmentation

Critically Threatened Ecosystems in Pakistan Source: GOP, 1999. Biodiversity Action Plan of Pakistan, Ministry of Environment/IUCN/WWF, Islamabad.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) released a critical report in 2019 that provides a thorough evaluation of global biodiversity, demonstrating that climate change is a major driver of biodiversity loss. This loss not only represents a crisis for natural ecosystems but also undermines human health, livelihoods, and food security, as people depend on biodiversity for a range of ecosystem services (IPBES, 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019).

3.9. The Implications of Recent Climate Changes

The recent trends in climate change, including accelerated glacial melt, ocean warming and acidification, and biodiversity loss, have far-reaching implications. These changes affect everything from global sea levels to the fundamental processes that support life on Earth. The loss of biodiversity and the decline of marine and terrestrial ecosystems compromise the planet's ability to sustain human life and maintain the natural balance.

3.10. Impact on Social / Daily Life

Climate change significantly influences social and daily life, creating distinct challenges for communities depending on their geographical and environmental context. River-fed areas, which benefit from a consistent supply of water, are facing increasingly unpredictable water flow patterns due to climate change. This unpredictability can lead to floods or droughts, disrupting traditional agricultural practices, drinking water supplies, and the generation of hydropower. Non-river-fed areas, often dependent on rain-fed agriculture or finite groundwater sources, encounter heightened risks of water scarcity, demanding innovative water management and conservation strategies to sustain livelihoods and maintain ecological balance.

3.11. River Fed Areas vs. Non River Fed Areas

In river-fed regions, the variability in water availability due to climate-induced changes poses a significant risk to agriculture, biodiversity, and the provision of hydropower. How altered precipitation patterns and melting glaciers impact river flow, affecting both human communities and wildlife that rely on stable aquatic environments (Altered rainfall patterns increase forb abundance and richness in native tallgrass prairie, 2016).

Conversely, non-river-fed areas, more prone to experiencing drought conditions, face challenges in securing water for agriculture and daily needs. The vulnerability of these regions to prolonged dry spells exacerbated by climate change, stressing the importance of enhancing groundwater recharge and promoting water-saving technologies to mitigate these impacts (Changes in intense rainfall events and dry periods across Africa in the twenty-first century, 2019).

3.12. Implications for Irrigation and Hydel Power

The implications of climate change for irrigation and hydropower, particularly in the context of reduced snowfall in regions like Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K), present significant challenges and necessitate a strategic response to ensure water availability and energy security. The altering river flows and the increased reliance on groundwater extraction due to changing precipitation patterns have direct impacts on agricultural productivity, hydropower generation, and regional water management strategies.

In river-fed areas, irrigation systems are highly dependent on consistent river flows, which are being increasingly affected by climate change. The variability in water availability due to reduced snowfall and altered precipitation patterns can lead to water scarcity, affecting crop yields and food security. Implementing adaptive irrigation strategies, such as the development of more efficient water use practices and the adoption of drought-resistant crop varieties, becomes imperative to mitigate these impacts.

Advancements in irrigation technology, including drip and sprinkler systems, can significantly reduce water wastage and improve water use efficiency in agricultural practices. Such technologies are essential in areas experiencing water scarcity due to reduced snowfall and changing hydrological patterns.

Hydropower, a major source of renewable energy in GB and AJ&K, is also vulnerable to the impacts of climate change. Variations in river flow, directly linked to snowfall and glacier melt patterns, can lead to fluctuations in hydropower production. Enhancing the resilience of hydropower systems to climate variability is crucial for maintaining energy security and supporting sustainable development in these regions.

Developing integrated approaches to water and energy management can help optimize hydropower production while ensuring adequate water for irrigation. This includes the use of advanced forecasting models to predict water availability and adapt hydropower operations accordingly.

3.13. Effect on the Livelihood of People

The effects of climate change, particularly the reduced snowfall in regions like Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K), have profound implications on the livelihoods of local populations. The variability in water availability, stemming from diminished snowfall, not only disrupts traditional agricultural practices but also impacts the broader socio-economic fabric of these communities.

In river-fed areas, communities that have historically depended on predictable water flow for irrigation, fishing, and hydropower generation are finding these resources increasingly unreliable. Reduced snowfall leads to lower river volumes, affecting water availability for agriculture, reducing fish stocks due to changing habitats, and compromising hydropower production due to fluctuating water levels. These changes pose significant risks to the economic stability and food security of local populations, highlighting the need for adaptive strategies to safeguard livelihoods.

Conversely, non-river-fed areas face their own set of challenges. The dependence on rain-fed agriculture and groundwater in these regions makes them particularly susceptible to climate change impacts. As reduced snowfall contributes to less recharge of groundwater sources and unpredictable rainfall patterns, agricultural productivity is threatened, jeopardizing the primary source of livelihood for many communities. The resultant water scarcity not only affects agricultural sustainability but also the availability of drinking water, further exacerbating the vulnerability of these communities to climate change.

The direct linkage between water availability and agricultural output cannot be overstated. In GB and AJ&K, where agriculture forms the backbone of the economy, the reduced snowfall and ensuing water scarcity have led to lower crop yields, threatening food security and livelihoods. This situation is exacerbated by the lack of alternative employment opportunities in these predominantly rural areas, placing additional economic pressures on already vulnerable communities.

3.14. Overall Environmental Quality (Including Smog Issues)

Climate change exacerbates environmental degradation, affecting air quality and leading to increased occurrences of smog, particularly in urban and industrialized regions. Singh and Gupta (2020) highlight how rising temperatures contribute to the formation of ground-level ozone, a key component of smog, which poses health risks and affects daily life, especially in densely populated areas.

Moreover, the loss of biodiversity and natural habitats, a consequence of altered precipitation patterns, deforestation, and land use changes, further diminishes environmental quality. The degradation of ecosystems undermines their ability to provide essential services, including air and water purification, carbon sequestration, and the maintenance of biodiversity.

4. Strategic Response to Climate Change

Developing a comprehensive strategic response to climate change involves constructing a robust framework for strategy and action plans, establishing the scope and guiding principles, and detailing mitigation measures across various levels, including local initiatives and the role of local government and national government or army involvement. Given the constraints, I will outline the key components of such a strategy, referencing recent studies to provide a foundation for these approaches.

4.1. Framework for Strategy and Action Plan

The strategic response to the diminishing snowfall and its cascading effects in GB and AJ&K requires a multidimensional approach. This strategy should be built on a foundation that appreciates the interconnectedness of environmental integrity, economic viability, and social equity. The objectives laid out must be clear and measurable, aiming to mitigate the impacts of reduced snowfall on water resources, agriculture, and local livelihoods, while also enhancing the regions' resilience to climate change.

4.2. Objectives

4.3. Water Resource Management

Develop and implement integrated water resource management strategies to address the reduced snowfall and its impact on the water supply.

4.4. Sustainable Agriculture

Promote agricultural practices that are resilient to changing precipitation patterns and water availability.

4.5. Community Resilience

Enhance the adaptive capacity of local communities to withstand and recover from the impacts of reduced snowfall and other climate-induced changes.

4.6. Policy Integration

Ensure that climate change adaptation and mitigation are integrated into all relevant policy areas, with a specific focus on water management, land use, and disaster preparedness.

4.7. Research and Monitoring

Support ongoing research to monitor climate change impacts, particularly the reduction in snowfall, and to develop innovative solutions to these challenges.

4.8. Public Engagement

Foster a high level of public awareness and participation in climate resilience efforts, emphasizing the importance of community-led initiatives.

4.9. Infrastructure Upgrades

Invest in the development and maintenance of water conservation and storage infrastructures, such as dams, rainwater harvesting systems, and efficient irrigation techniques.

4.10. Afforestation Programs

Initiate large-scale afforestation and reforestation projects to increase groundwater recharge, reduce soil erosion, and enhance carbon sequestration.

4.11. Capacity Building

Conduct training and workshops for local farmers on climate-resilient farming techniques and for communities on water-saving practices and disaster risk reduction.

4.12. Scope & Guiding Principles

The scope of a climate change strategy tailored to address the impacts of reduced snowfall in Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K) must holistically consider the interlinked environmental, economic, and social dimensions. This comprehensive approach aims not only to mitigate the direct effects of climate change by reducing greenhouse gas emissions but also to enhance the resilience of these regions to adapt to changing climatic conditions, thereby supporting sustainable development that benefits both current and future generations.

4.13. Guiding Principles for a Comprehensive Strategy

Ensuring that strategies for adapting to and mitigating climate change promote the long-term health of the environment, economy, and society in GB and AJ&K. Sustainable practices must prioritize renewable energy, water conservation, and sustainable land use to preserve these regions' natural resources.

Addressing climate change with a focus on equity means ensuring that all segments of the population in GB and AJ&K, particularly the most vulnerable communities, have access to the resources and support they need to adapt to climate changes. Strategies must aim to distribute the benefits of climate action fairly and prevent any disproportionate impacts on marginalized groups.

Involving communities, local stakeholders, and indigenous peoples in the decision-making process is crucial. Inclusivity ensures that climate strategies are grounded in local knowledge and address the specific needs and priorities of those most affected by reduced snowfall and other climate change impacts.

Policies and actions should be informed by the latest scientific research and climate modeling. This includes utilizing studies that specifically examine the impacts of reduced snowfall on the hydrology, agriculture, and livelihoods in GB and AJ&K.

4.14. Mitigation Measures at Different Levels

Mitigation strategies must operate at multiple tiers, from international agreements to national policies and local actions, to be effective.

4.15. Tiers of Mitigation Strategies

Addressing the multifaceted challenges posed by climate change, particularly the reduced snowfall in Gilgit-Baltistan (GB) and Azad Jammu & Kashmir (AJ&K), requires a layered approach to mitigation strategies that operate across global, national, and local levels. These strategies are integral to reducing greenhouse gas emissions, enhancing ecological resilience, and ensuring sustainable development in these vulnerable regions.

4.16. Global Level Mitigation Strategies

At the global level, the participation of countries in international climate agreements like the Paris Agreement is crucial. These agreements set the stage for collaborative efforts in reducing emissions and adapting to climate change impacts. For regions like GB and AJ&K, which are significantly affected by reduced snowfall and subsequent water scarcity, global commitments to emission reductions and climate finance are vital. They help ensure the availability of resources for adaptation and mitigation projects tailored to the needs of these high-altitude areas.

Strengthening international cooperation to share knowledge, technologies, and financial resources is essential for regions heavily impacted by climate change. This includes initiatives like the Green Climate Fund, which supports projects in developing countries to enhance their resilience and adapt to climate change effects.

5. National Level Mitigation Strategies

At the national level, the development of comprehensive climate action plans is imperative. These plans should prioritize the transition to renewable energy sources, such as solar and wind, which not only reduce dependency on fossil fuels but also offer sustainable energy solutions for remote regions like GB and AJ&K. Enhancing energy efficiency across all sectors and promoting sustainable land use and forestry practices are equally important. These practices help in carbon sequestration and protect against land degradation, which can exacerbate the effects of reduced snowfall.

Establishing robust policy and regulatory frameworks that encourage investments in renewable energy, energy efficiency, and sustainable land management is crucial. This also involves updating building codes and urban planning guidelines to integrate climate resilience measures.

5.1. Local Level Mitigation Strategies

At the local level, the implementation of community-based initiatives plays a critical role in directly addressing the impacts of climate change. In GB and AJ&K, local resilience and adaptation strategies can significantly mitigate the effects of reduced snowfall.

Initiatives such as urban greening can help improve local microclimates, while sustainable transportation projects reduce overall emissions. Additionally, promoting local renewable energy projects, such as small-scale hydroelectric plants or solar power installations, can ensure energy security and sustainability in these areas.

Empowering local communities through education and involvement in climate action initiatives is vital. This includes programs aimed at enhancing awareness of climate change impacts and training in sustainable practices and technologies.

5.2. Local Level Initiatives

Local initiatives play a crucial role in climate change mitigation, involving community-led projects that reduce emissions and enhance resilience. These can include urban forestry programs, local renewable energy installations, and initiatives to improve public transportation and reduce reliance on fossil fuels.

5.3. Local Government Role

Local governments are pivotal in translating national climate goals into actionable local strategies. This involves integrating climate considerations into urban planning and development, enforcing building and environmental regulations to support sustainability, and facilitating community engagement and education on climate change issues.

5.4. Government / Army Involvement

At a broader level, government and, in some contexts, military involvement can provide critical support for large-scale infrastructure projects related to climate change mitigation and adaptation, such as coastal defense systems, reforestation projects, and the development of national renewable energy infrastructure. The army's role in disaster response and management also positions it uniquely to assist in climate-related emergencies.

5.5. National Disaster Management

The National Disaster Management Authority (NDMA) plays a pivotal role in addressing the multifaceted challenges posed by climate change. As climate-related disasters become more frequent and severe, the NDMA's responsibilities have expanded to include not only immediate disaster response but also long-term climate change mitigation and adaptation strategies.

The NDMA is tasked with coordinating national disaster response, mitigation, and recovery efforts. Its mandate has evolved to encompass climate change adaptation and mitigation, recognizing the intrinsic link between climate change and natural disasters. This involves comprehensive planning, capacity building, and the implementation of strategies to reduce the vulnerability of communities and enhance resilience.

5.6. Climate Change Mitigation Efforts

The National Disaster Management Authority (NDMA) plays a pivotal role in climate change mitigation, adopting a multifaceted approach that includes policy development and implementation, promoting renewable energy projects, and initiating afforestation and reforestation programs. These efforts are crucial for reducing greenhouse gas emissions and enhancing carbon sinks, directly contributing to the global fight against climate change.

5.7. Policy Development and Implementation

The NDMA collaborates with environmental agencies and stakeholders to integrate climate change mitigation into national disaster management policies. This collaborative approach ensures that climate change considerations are central to disaster risk reduction strategies, fostering a holistic approach to national security and sustainability.

Integrating Climate Action with Disaster Management: The NDMA's strategic planning involves updating national disaster management frameworks to include climate mitigation measures, ensuring that policies reflect the latest scientific research and international best practices (Impact of climate change on health in Karachi, Pakistan, 2021).

5.8. Renewable Energy Projects

The shift towards renewable energy sources is a key strategy in reducing dependency on fossil fuels, a major contributor to global greenhouse gas emissions. The NDMA's role in promoting renewable energy projects includes advocating for policy support, facilitating funding, and raising public awareness about the benefits of renewable energy.

Supporting Renewable Energy Initiatives: By partnering with energy departments and private sectors, the NDMA helps to implement solar, wind, and hydroelectric projects that contribute to a sustainable and resilient energy infrastructure.

5.9. Afforestation and Reforestation Programs

Afforestation and reforestation are critical for enhancing carbon sequestration capabilities, mitigating the effects of climate change, and reducing the vulnerability of landscapes to disasters such as landslides and floods. The NDMA supports these programs by securing funding, engaging communities, and monitoring project impacts.

Tree Planting Initiatives: Through community-based programs, the NDMA facilitates the planting of millions of trees across vulnerable areas, aiming to restore degraded lands, improve water retention, and contribute to biodiversity conservation (Towards empowerment of the renewable energy sector in Pakistan for sustainable energy evolution: SWOT analysis, 2020).

5.10. Climate Change Adaptation Strategies

Adaptation to climate change involves a broad spectrum of strategies aimed at reducing the vulnerability of communities and enhancing their capacity to manage the adverse effects of climate change. These strategies are crucial for sustaining development and ensuring the security of livelihoods in the face of increasing climatic uncertainties.

5.11. Infrastructure Resilience

Upgrading and reinforcing infrastructure to withstand extreme weather events are critical components of climate change adaptation. This includes the development of flood defenses, construction of storm-resistant buildings, and the establishment of drought-resistant water supply systems. The goal is to create an infrastructure capable of resisting the impacts of climate change, thereby minimizing human and economic losses.

5.12. Flood Defenses

Implementing advanced engineering solutions to protect coastal and riverine communities from storm surges and flooding. This could involve the construction of sea walls, flood barriers, and the restoration of natural buffers such as mangroves and wetlands.

5.13. Storm-Resistant Buildings

Developing building codes and standards that ensure new constructions and existing structures are resilient to storms and high winds. This includes the use of durable materials and designs that minimize potential damage.

5.14. Drought-Resistant Water Supply Systems

Establishing water conservation practices, rainwater harvesting systems, and the development of alternative water sources to ensure a reliable supply during periods of drought.

5.15. Community Awareness and Preparedness

Building community resilience is essential for effective adaptation to climate change. This involves raising awareness about climate change and its impacts, educating communities on disaster risk reduction, and conducting preparedness drills. Such initiatives empower communities, enabling them to respond more effectively to disasters and climate-related threats.

5.16. Public Awareness Campaigns

Utilizing media, workshops, and educational programs to inform the public about the risks associated with climate change and the importance of adaptation measures.

5.17. Disaster Preparedness Drills

Organizing regular drills and simulations to ensure communities are prepared for extreme weather events, improving response times and reducing casualties during actual disasters.

5.18. Agricultural Adaptation

The agricultural sector is particularly vulnerable to climate change, with impacts including altered rainfall patterns, increased temperatures, and the prevalence of pests and diseases. Supporting climate-resilient agricultural practices is vital for food security and the livelihoods of rural communities.

5.19. Climate-Resilient Crops

Developing and promoting the use of crop varieties that are resistant to drought, floods, and increased temperatures. This also involves implementing sustainable agricultural practices that enhance soil health and water efficiency.

5.20. Water Management Techniques

Adopting advanced irrigation technologies and water management practices that optimize water use and reduce wastage, ensuring crops receive adequate water even during periods of scarcity.

6. Integrated Pest Management (IPM)

Utilizing IPM strategies to control pest populations through environmentally friendly means, reducing the reliance on chemical pesticides and enhancing crop resilience.

6.1. Enhancing Early Warning Systems

Early warning systems are crucial for minimizing the impact of climate-induced disasters. The NDMA works to:

6.2. Improve Forecasting Techniques

Leveraging advanced meteorological technologies for accurate and timely weather forecasts.

6.3. Public Alert Systems

Developing effective communication channels to disseminate warnings to at-risk populations promptly.

6.4. Cross-Border Collaboration

Engaging in regional cooperation for disaster warning and response, particularly for transboundary hazards.

7. Conclusion

As the planet warms, the impacts of climate change become increasingly evident and devastating, particularly in sensitive and ecologically critical regions like Gilgit-Baltistan and Azad Jammu & Kashmir. These areas, characterized by their significant biodiversity and crucial water resources, stand on the frontline of climate adversity, witnessing profound shifts in their climatic patterns, glacier dynamics, and hydrological regimes. The rapid melting of glaciers, erratic precipitation patterns, and the increased frequency of extreme weather events underscore the immediate need for comprehensive and integrated strategies to mitigate these impacts and adapt to the changing climate.

The role of National Disaster Management Authorities (NDMAs) in orchestrating a coordinated response to climate change is more critical than ever. Through policy development, implementation of renewable energy projects, and afforestation and reforestation programs, NDMAs have a unique opportunity to lead the charge in mitigating greenhouse gas emissions and enhancing carbon sinks. However, mitigation is only one side of the coin. Adaptation strategies, focusing on infrastructure resilience, community awareness and preparedness, agricultural adaptation, and the enhancement of early warning systems, are equally vital to reduce the vulnerability of communities and secure livelihoods against the backdrop of climatic uncertainties.

Infrastructure resilience, with its emphasis on flood defenses, storm-resistant buildings, and drought-resistant water systems, provides a foundational layer of security that enables communities to withstand the impacts of extreme weather events. Similarly, fostering community awareness and preparedness equips individuals with the knowledge and skills necessary to navigate the challenges posed by climate change, enhancing societal resilience from the ground up.

Agricultural adaptation is another critical area, necessitating the adoption of climate-resilient crops, water management techniques, and integrated pest management strategies to ensure food security in the face of changing climatic conditions. The advancement of early warning systems, leveraging cutting-edge meteorological technologies, plays a pivotal role in minimizing the human and economic toll of climate-induced disasters, offering communities a crucial lead time to prepare and respond effectively.

The journey towards a resilient and sustainable future in the face of climate change is fraught with challenges, requiring the collective effort of governments, communities, and individuals alike. It demands a shift in perspective, recognizing that climate change is not a distant threat but a present reality that affects every aspect of our lives. The integration of climate change mitigation and adaptation

strategies into national disaster management frameworks represents a holistic approach to safeguarding our planet and ensuring the well-being of current and future generations.

As we move forward, the lessons learned from regions like Gilgit-Baltistan and Azad Jammu & Kashmir must inform global strategies and actions. It is imperative that we harness the power of innovation, technology, and collaborative governance to create adaptive, resilient, and sustainable communities. The fight against climate change is a testament to our collective resolve to protect our planet and secure a livable future for all. In this critical endeavor, the role of NDMAs, supported by robust policies, public engagement, and international cooperation, is indispensable, marking a beacon of hope and action in the global climate narrative.

7.1. Recommendations for Addressing Climate Change Impacts

In light of the challenges posed by climate change, particularly in regions like Gilgit-Baltistan and Azad Jammu & Kashmir, a set of targeted recommendations is essential for effective mitigation and adaptation. These recommendations focus on strengthening policies, enhancing collaboration, and leveraging technology for sustainable outcomes.

- Governments must prioritize the development of comprehensive climate policies that are integrative, inclusive, and forward-looking. These policies should encompass both mitigation strategies, like transitioning to renewable energy, and adaptation measures, such as infrastructure resilience and sustainable agricultural practices.
- Effective climate action requires collaboration across various sectors. This includes partnerships between government agencies, private sectors, non-governmental organizations, and local communities. Collaborative efforts should aim to share knowledge, pool resources, and align strategies for a unified approach to climate change.
- Empowering local communities through education and participation in climate action is crucial. Initiatives such as community-based resource management, local conservation efforts, and public awareness campaigns can significantly enhance local resilience and adaptive capacity.
- Increased investment in climate science, innovative technologies, and best practices is essential to understand and combat climate change effectively. This includes research in renewable energy, climate-resilient crops, and advanced forecasting technologies.
- Infrastructure development should incorporate climate resilience as a core principle. This involves designing and constructing buildings, roads, and other infrastructure elements that can withstand extreme weather conditions and climatic shifts.
- Strengthening early warning systems for better prediction and timely response to climate-related disasters is vital. Additionally, regular disaster preparedness drills and emergency response training should be conducted to ensure community readiness.
- Climate change is a global challenge that requires international collaboration. Sharing knowledge, experiences, and resources at the international level can facilitate the implementation of effective climate solutions and foster global solidarity in climate action.
- Supporting sustainable agricultural practices that are resilient to climate change is essential for food security. This includes promoting water-efficient irrigation, organic farming, and the use of climate-resilient crop varieties.
- Economic development strategies should align with environmental sustainability. This involves promoting green industries, sustainable tourism, and eco-friendly practices that contribute to economic growth while conserving the environment.
- Raising public awareness about the impacts of climate change and the importance of sustainable practices is fundamental. Educational programs and campaigns should aim to inform and engage the public, fostering a culture of environmental stewardship and collective responsibility.

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