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Research Article

A STUDY ON THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN KASHMIR

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Abstract

Research and investigation was carried out on the assessing the impacts of climate change on water resources in Kashmir. Water resources are important to both society and ecosystems. We depend on a clean supply of drinking water to sustain our health. We also need water for agriculture, energy production, recreation, and manufacturing and host of almost all life activities on this planet. However Climate Change is likely to impact freshwater resource availability and thereby disturbing hydrological cycle, which may affect the spatial and temporal distribution of runoff, soil moisture, and ground water reserve and may increase droughts and floods. In J&K, increased water demand due to urbanization, agriculture expansion, increasing population, rapid industrialization and economic development has already put pressure on water and climate change is likely to exacerbate it. This paper's primary goal is to investigate how climate change affects water availability and resources for a variety of sectors, including ecosystems, agriculture, and human health.

Keywords: Climate Change, Precipitation, Discharge, Temperature, Discharge Fluctuation, Time series analysis

I. INTRODUCTION

Kashmir valley occupies only about 15,520 sq.km of the total area of 2,22,236 sq.km. of the state of Jammu and Kashmir which is about 7% of the total area, but accommodates more than the half of the ten million population of the State10. The people are mainly engaged with the agriculture and horticulture activities and therefore depending more upon the availability of the water resources. Effective design of sustainable development will require an understanding of the existing scenario of the climate in the study area. The present study attempts to find out how variability in climate is occurring in study area, in terms of the temperature change. The Kashmir valley has a totally different climate and it has been found difficult to classify the region in a specific climate regime. Physiography plays a vital role in framing the weather processes of the Kashmir valley. The study area, located in the Western Himalayas receives a high amount of precipitation during the winter season, mainly in the form of snow. The Indian monsoon air masses, which bring significant rainfall on the southern margin, penetrate infrequently across the Himalayas. However the precipitation in these northern ranges is concentrated in winter and spring months1. Winter precipitation is mainly attributed to the passage of weather systems called western disturbances. These are eastward moving low pressure synoptic weather systems that originate over the Mediterranean Sea or mid–Atlantic Ocean and travel eastward over Iran, Afghanistan, Pakistan and Northwest, take their Southernmost tracks during winter and pass over Northwestern India.24 The winter precipitation provides the principal source for accumulation on Western Himalayan (Indus basin) glaciers in the greatest area of perennial ice outside the Polar Regions.

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The state of Jammu and Kashmir is broadly divided into three physical regions; Sub-Himalayan Jammu, Himalayan Kashmir and Trans-Himalayan Laddakh. Out of these three, the study area, Kashmir valley, lies in the Himalayan Kashmir. It falls between 33015' and 34045' North Latitudes and 73045' and 75015' East Longitudes. The study area(Fig.1) is an oval shaped intermontane basin called Jhelum basin, a sub-basin of Indus River basin, running in NW-SE direction and covering nearly an area of 15,520 sq.km. Of the total area of 2,22,236 sq.km. of the state of Jammu and Kashmir. The Greater Himalaya (Zanskar Range) divides the Kashmir Valley from Laddakh in North while the Pirpanjal Range, which encloses the valley from the West and the South, separates it from the Great Plains of Northern India. The main range of the Himalayas runs along the Northeastern flank of the valley. The valley narrows itself towards the North with massive structures of the Kaji Nag Range. This valley part has an average height of 1,850mabove mean sea level (msl) but the surrounding mountains rise from 3000m to about 5400m above msl. The climate in Kashmir is sharply marked by its seasonality. The climate of Kashmir valley may be placed in the dfb category of Koppen's classification of climate, having humid severe, raw winters and short summers14. On the basis of temperature and precipitation in Kashmir valley, the year has been divided into four seasons19. There is one hot and other cold and in between these are two warm seasons. These seasons have been identified as below:

a. Winter- November to February
b. Spring- March to April
c. Summer- May to August and
d. Autumn- September to October

The cold winter season is followed by the warm spring season. The warm spring season is followed by the hot summer season, which is followed by the moderate autumn season.

Climate change is a long term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years.it may be a change in the average weather conditions or a change in the distribution of weather events with respect to an average e.g. greater or fewer extreme weather events. Climate change may be limited to a specific region or may occur across the earth. Global warming is one of the major climate changes that have direct impact on redistribution of water resources on the earth. The observed warming over several decades due to rising atmospheric carbon dioxide (CO_2) and other greenhouse gases has been associated with the change in number of components of hydrological cycle systems such as increasing atmospheric water vapor content, increasing evaporation, changing precipitation patterns, intensity and extremes; reduced snow cover; and changes in soil moisture and runoff (Huntington, 2006). The frequency of heavy precipitation events has increased over most areas. There have been significant decreases in water storage in mountain glaciers and northern hemisphere snow cover. Shifts in the amplitude and timing of runoff in glaciers and snowmelt fed rivers and ice related phenomena in the rivers and lakes have been observed. As the climate warms through the twenty first century, glaciers and ice caps are projected to lose mass owing to dominance of summer melting over winter precipitation increase. Based on simulation of eleven glaciers in various regions, a volume loss of 60% of these glaciers is projected by 2050 thus reducing water availability during warm and dry periods in regions supplied by melt water from major mountain ranges. Globally, the areas of land classified as very dry has more than doubled since 1970s (IPCC Technical paper IV, June 2008). These trends are predicted with a high degree of confidence to continue and accelerate during the current century.

The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs. The climate of Kashmir has also witnessed a change over the past decades somewhat in similar fashion as rest of the world, with precipitation decreasing over years especially its distribution during a particular season. Besides, the state is rich in fresh water resource making it more vulnerable to climate change as there are abundant evidences that fresh water resources have the potential to be strongly impacted by the climate change with wide ranging consequences for human societies and ecosystem. The world famous Wular Lake located in north Kashmir valley which is mainly Jhelum River fed would be a victim of climate

change. Despite the threats faced by the state due to climate change and its ecological fragility, very less work has been done to ascertain the impact on various environmental components. Also, it was found that no scientific study has been taken up for impact assessment of climate change on various water resources and watersheds, thus, necessitating a preliminary assessment of the area in this field. The present study was taken as a small initiative on this front.

II. REVIEW OF LITERATURE

1. Avay Risal et al. 2020 conducted a study on "Impact of Climate Change on Water Resources and Crop Production in Western Nepal: Implications and Adaptation Strategies" in this study the irrigation-led farming system intensification and efficient use of ground and surface water resources are currently being championed as a crucial ingredient for achieving food security and reducing poverty in Nepal. The potential scope and sustainability of irrigation interventions under current and future climates however remains poorly understood. Potential adaptation options in Western Nepal were analyzed using bias-corrected Regional Climate Model (RCM) data and the Soil and Water Assessment Tool (SWAT) model. The RCM climate change scenario suggested that average annual rainfall will increase by about 4% with occurrence of increased number and intensity of rainfall events in the winter. RCM outputs also suggested that average annual maximum temperature could decrease by 1.4 _C, and average annual minimum temperature may increase by 0.3 _C from 2021 to 2050. Similarly, average monthly stream flow volume could increase by about 65% from March–April, although it could decrease by about 10% in June. Our results highlight the tight hydrological coupling of surface and groundwater. Farmers making use of surface water for irrigation in upstream sub basins may inadvertently cause a decrease in average water availability in downstream sub basins at approximately 14 %, which may result in increased need to abstract groundwater to compensate for deficits. Well-designed irrigated crop rotations that fully utilize both surface and groundwater conversely may increase groundwater levels by an average of 45 mm from 2022 to 2050, suggesting that in particular sub basins the cultivation of two crops a year may not cause long-term groundwater depletion. Modeled crop yield for the winter and spring seasons were however lower under future climate change scenarios, even with sufficient irrigation application. Lower yields were associated with shortened growing periods and high temperature stress. Irrigation intensification appears to be feasible if both surface and groundwater resources are appropriately targeted and rationally used. Conjunctive irrigation planning is required for equitable and year-round irrigation supply as neither the stream flow nor groundwater can provide full and year-round irrigation for intensified cropping systems without causing the degradation of natural resources.

2. Humaira Qadri and Ishtiyak Ahmad Dar 2020 conducted a study on "Preliminary Study on the Changing Patterns of Temperature and Precipitation of Srinagar, Kashmir, India" In this paper an attempt has been made to identify the trends of temperature and precipitation in the Srinagar. The data pertaining to temperature and precipitation was collected from the IMD, Meteorological Centre Rambagh, Srinagar for the period 1987-2014.The study has analyzed monthly, seasonal and annual temperature and precipitation trends over Srinagar. The result of the study revealed an increasing trend in the annual and seasonal mean temperature and mixed trend in the monthly average temperature. Observation of the existing data revealed clear trends of both increasing and decreasing precipitation on monthly, seasonal and yearly basis. An analysis of the mean annual and winter precipitation has revealed declining trend. This unusual change or variation in temperature and precipitation is probably due to large scale changes in the land use –land cover witnessed by the study area during the period 1982-2011. The trend analysis reveals that annual mean temperature of Srinagar is projected to increase by 0.60 ^{O}C up to the year 2031 whereas the mean annual precipitation is projected to decrease 6.1 mm by the year 2031.Thus such increase in temperature and decrease in precipitation over Srinagar in future may pose serious threat on agriculture, drinking water supply, horticulture, availability of water for irrigation, water resources, economy, recreational use of water and the tourism.

3. Mehvish Hameed et al. 2017 conducted a study on "Assessing the impact of climate change on surface water resources of Wular Lake" The authors said that the discharge of river Jhelum at Asham Inlet was obtained of the previous 21 years, and formatted to a pre-requisite form. Also the climatic data viz. temperature, precipitation, etc. were obtained from the metrological station. The three main variables of study were used as discharge, temperature and precipitation; discharge being the response variable with respect to the remaining two. Trend lines were established for each of the variables with the help of the moving averages of 5 years; which revealed the increasing trend in the temperature and the decreasing trend in the discharge and the precipitation. The trend of the three parameters was in accordance with the global climatic and hydrological findings. Further, to analyse the findings, Mann-Kendall's tests was used to ascertain the results. As per this test, temperature indicates a significant trend at 10% significance level with a p-value of 0.0494 while the precipitation could not reveal any significant trend over the limited time frame of study even at 10% significance level, which could be a result of the seasonal dimension to it. The discharge displayed a no trend over the given period of study at 5% significance levels. Further Kendall correlation test was done on the three variables of study; a significant correlation between mean annual temperature and annual rainfall was found, the magnitude of correlation coefficient being 0.46. A significant correlation was found between the annual rainfall and the mean annual discharge and correlation coefficient value of 0.65 was observed. Also a weak correlation was found between mean annual discharge and mean annual temperature; the coefficient value was found to be 0.6190. The results are in accordance with the global findings which depict rising global temperatures and decreasing precipitation. The given study concluded that there was an adverse effect of the climate change on the catchment of the Wular Lake as visible by the various tests.

4. Rashid Mahmood and Shaofeng Jia 2016 conducted a study on the "Assessment of Impacts of Climate Change on the Water Resources of the Trans boundary Jhelum River Basin of Pakistan and India" The authors said that the Pakistan's economy is significantly reliant on agriculture. However, Pakistan is included in the most water-stressed countries in the world, and its water resources are considerably vulnerable to climate variability and climate change. Therefore, in the present study, the water resources of the Jhelum River basin, which provides water to 6 million hectares of land of Pakistan and hydropower production, were assessed under the scenarios A2 and B2 of HadCM3. A hydrological model, Hydrologic Modeling System (HEC-HMS), was set up, calibrated, and validated for the Jhelum basin, and then stream flow was simulated for three future periods: 2011–2040, 2041–2070, and 2071–2099.The simulated stream flow of each period was compared with the simulated stream flow of the baseline period (1971–2000) to find the changes in the following indicators: mean flow, low flow, median flow, high flow, and center-of-volume dates (CVDs). The results of the study showed an increase of 10%–15% in the mean annual flow as compared to the baseline flow at the end of this century. Winter, spring, and autumn showed an increase in stream flow at most of the sites in all three periods. However, summer (the monsoon season in the basin) showed decreased stream flow at most of the sites. Maximum increase at Azad Pattan was projected in winter in the 2080s, with about 37%–39%increase in flow under both scenarios. Low and median flows were projected to increase, but a decline in high flow was detected in the future under both scenarios. It was also concluded that half of the annual flow in the basin will pass by the Azad Pattan site one week earlier than it does now. On the whole, the Jhelum basin would face more temporal and magnitudinal variations in high, low, and mean flows relative to present conditions. This shows that without a consideration of climate change impacts, proper utilization and management of water resources in the basin will be more difficult.

III. CLIMATE CHANGE AND INDIA

A collection of perspectives on climate change in India outlines the need for greater debate on the links between climate change and development processes in the country. Climate change is no longer a worry for the environment. It has emerged as the world's most significant developmental problem.

Its economic consequences, particularly for the poor, make it a key governance concern. The debates and discussions that are taking place in preparation for the next conference of parties (CoP) in Copenhagen and beyond are an indication of this. One of UNDP's contributions to the broader development process is discussion, particularly from the perspective of the poor. This collection of articles gathers and disseminates some Indian opinions on climate change. From arguing for a new climate pact to emphasising the importance of the small-scale industrial sector in climate change debates, some of India's most well-known environmentalists, economists, and policymakers have expressed their worries and convictions in this collection. According to Sunita Narain, "there isn't much of a distinction between maintaining a local forest and controlling the global climate." Both are examples of common property resources. What is most urgently need is a property rights framework that fosters cooperation." Prodipto Ghosh distinguishes between realities and fictions by deconstructing six misconceptions based on India's stance on climate change. His research shows that a country may have both growth and lower carbon emissions. NC Saxena discusses the implications of climate change on food security in India, which is already under threat from a variety of other factors. He is a major supporter of climate change adaptation through soil and water conservation. Jyoti Parikh has discovered women's unique vulnerability to climate change. She argues for incorporating gender into climate change debates and conversations. Preeti Soni has brought to light an essential yet underappreciated sector: small-scale enterprises. Small-scale enterprises create significant amounts of greenhouse emissions and have the ability to save enormous amounts of energy.

IV. CLIMATE CHANGE IN KASHMIR'S HIMALAYAN LANDSCAPE

Climate change has accelerated the already rising temperature and unstable precipitation patterns and worsened the vulnerabilities to drought, thereby bringing the Himalayan ecosystem to naught. As per the findings of the article, "Recent Glacier changes in Kashmir Alpine Himalayas, India" glaciers have shrunk by 17%. Another study 'Linking the recent glacier retreat and depleting stream flow patterns with land system changes in Kashmir Himalaya (India)' examined changes in the Kolahoi Glacier between1962 and 2018, and reveals that the glacier is receding at an alarming rate. It has lost almost 23% of its land, splitting into smaller pieces since 1962. As per IPCC, the glacial meltdown is projected to swell flooding; avalanches from snow slopes will become rampant and erode water supplies down the river stream. Another study reveals that the annual precipitation is likely to plummet by a maximum of 2.09–6.61% in the 2080s. Along with, during the 2080s, the seasonal distribution of precipitation is predicted to change dramatically, with reductions of 9%, 5.7 %, and 1.7%, respectively, in the winter, spring, and summer seasons. In light of the above-stated climatic transformations that have and will continue to cause life-altering events, it is important to understand, assess and evaluate the impact accounted by climate change in the Kashmir Himalayas. A study that maps climate hotspots over the forest cover in India using computer-model-based temperature and rainfall has been conducted for the three future time periods i.e. years 2030, 2050, and 2085. It has been observed that the biggest temperature rises are expected in Ladakh, Jammu-Kashmir, Himachal Pradesh, and Uttarakhand. Ladakh, Jammu & Kashmir, and Himachal Pradesh are expected to witness the smallest increases in rainfall if any at all

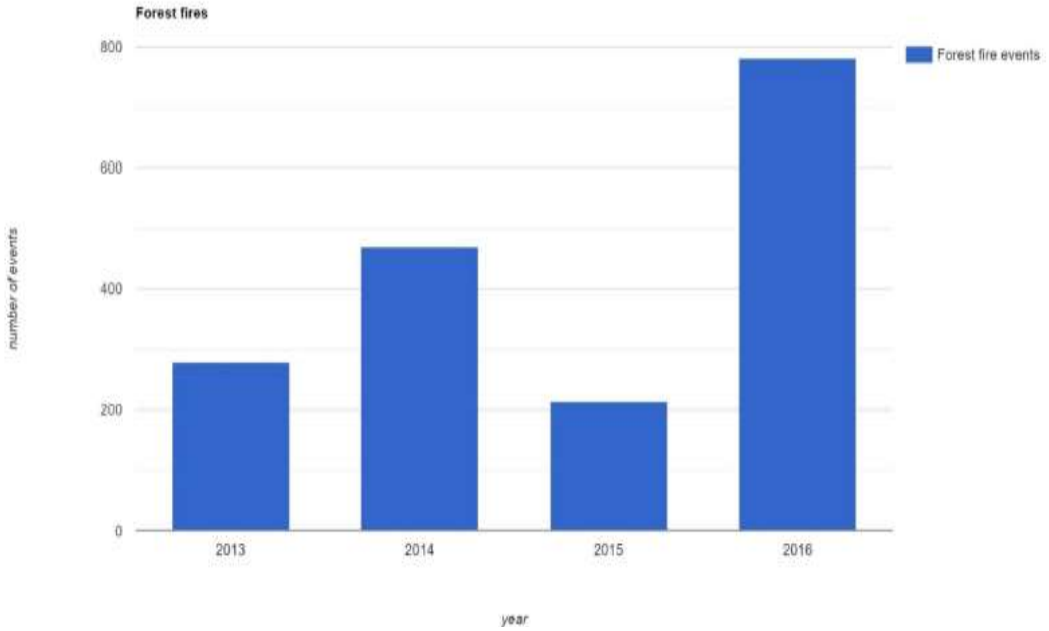
Table-1
Temperature Variation at Srinagar

Sl. No.	Month	1985	1990	1995	1996	1997	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1.	January	-1.3	-1.1	-4.7	-2.7	-3.2	-0.8	-2.0	-3.6	-2.8	-2.9	0.3	-0.3	-01.3	-02.5	-02.5	0.4	-01.5
2.	February	-1.3	1.5	-0.7	0.7	-0.8	2.2	-0.3	-0.3	-0.5	0.4	1.1	0.7	03.3	02.9	01.4	1.5	00.4
3.	March	4.7	2.5	3.4	4.9	4	4.6	2.9	3.2	4.5	3.7	5.6	5.3	04.7	03.0	05.3	5.0	06.5
4.	April	8.6	6.9	7.4	7.5	7.4	8.3	7.9	8.5	8.6	8.6	8.5	7.1	07.2	08.9	07.7	8.0	09.0
5.	May	10.9	11.9	10.5	10.0	9.6	11.4	13.2	14.5	11.3	9.1	10.7	9.9	13.3	11.9	11.5	10.8	11.1
6.	June	14.1	16.3	14.1	15.4	14.7	14.4	16.3	17.4	15.2	14.9	15.0	14.4	14.7	16.0	18.3	13.0	13.5
7.	July	19.1	18.5	18.7	17.8	20	18.4	18.7	19.5	17.1	18.9	16.9	18.0	19.3	17.8	19.1	16.9	17.7
8.	August	17.9	18.3	18.5	17.5	17.1	17.3	17.7	17.6	18.2	17.1	17.1	16.9	18.3	17.8	17.8	17.9	18.8
9.	September	12.5	14.1	11.4	13.8	13.8	14.5	11.3	11.2	11.6	13.6	12.6	13.7	12.3	13.3	11.3	11.9	13.3
10.	October	6.5	4.7	6.5	5.9	7.6	5.1	5.6	6.1	6.6	5.1	6.2	5.8	08.0	03.9	06.9	5.1	07.3
11.	November	0.3	0.3	-0.6	1.1	2.3	2.5	2.5	0.9	0.7	0.7	1.1	-0.02	03.5	-01.1	01.0	0.5	02.2
12.	December	-0.8	-1.7	-0.3	-3.1	0.5	-3.9	-0.7	-0.9	-0.8	0.0	-0.7	-0.03	00.0	-02.0	00.7	-0.8	-3.7

Source: State Action Plan on Climate Change (Jammu and Kashmir)

Additionally, according to the ENVIS newsletter (October-December, 2015) titled, "Climate Change and concerns of J&K": Temperate deciduous, cool mixed, and conifer forests have grown significantly (11%) at the expense of alpine meadows, which are expected to shrink. Socio-economically, the repercussions are nothing less than a catastrophe as the Kashmir valley and Jammu wrestle to preserve its pristine flora comprising of Deodar, Fir, and spruce. Surprisingly, the Blue pine and Chir pine are left unscathed from the blight of climate change. Not only the flora but fauna of Jammu & Kashmir seem to be in deep waters. In recent times, the phenomenon of bird migration has witnessed peculiar trends, especially in the wetlands of Jammu, Kashmir, and Ladakh throughout the winter. The latest Asian Water bird Census Report highlighted the richness and abundance of water birds, as well as the trend in the water bird population during five years of extensive surveys from 2015-to 2021, revealed that Kashmir has recorded a total of 6.4 lakh birds. Nonetheless, the number has decreased by 1.5 lakh since 2020. The region's two Ramsarsites Hokersar wetland and Wular lake have seen a significant drop in the number of incoming birds. The census states that "birds in Hokersar wetland decreased from 4.8 lakh in 2020 to 65,000 in 2021, while birds in Wular decreased from 1.2 lakh to 707 birds in2021".

The scourge of climate change is evident with the intensification of forest fires. It is not surprising to know that forest fires due to rising heat waves are on surge in Kashmir Himalayas. Forest fires are frequent in the subtropical woods of the Jammu region, although their intensity and frequency have been low in the Kashmir region. However, as a result of global climate change, winter precipitation has been below average for the last few years, resulting in a dry fall, which produces an atmosphere conducive to forest fires. The region has thus witnessed an increased incidence of forest fires. According to the Forest Department's official report, the year 2016 had unprecedented forest fire incidences. "In the state, there were about 781 forest fire occurrences registered." There search noted that "these infernos affected an astounding 2556.3 hectares, which is more than 200 percent greater than the equivalent year 2015." "Of the 781 events documented, 289 were fire incidents in Kashmir and 492 in the Jammu region," according to the report. "In 2015, there were 214 fire events across the state, affecting 341.4 hectares of land. The state had 470 and278 forest fire incidents in 2014 and 2013, respectively," according to the report. The report notes that the number of forest fires in 2016 was higher than in prior years.



We have understood how detrimental climate change can be for humans, culture, and ecology. However, to understand the consequences of climate change in Jammu and Kashmir, digging out the causes is a prerequisite. In J&K, unplanned urban growth, conflicts, changing socioeconomic profiles, excessive and unplanned exploitation of natural resources (like Dal Lake or deforestation), unplanned construction, climate variability and change, and many other factors all contribute to increased vulnerability to the Himalayan ecology. Key human interventions such as encroachment, pollution, siltation, and increasing resource exploitation, together with insufficient and improper planting, have a significant negative influence on the Himalayan environment.

This regressive trend may be stopped with sustainable development practices that strive for balanced growth. Bearing in mind the harmful effects of climate change, the Government of Jammu and Kashmir introduced the Sustainable Himalaya Mission. The Sustainable Himalaya Mission aims to:

i) A comprehensive investigation of the effects of climate change on species of plants, animals, and glacial ecology;
ii) Research on the sensitivity of mountain ecosystems;
iii) Participation of the community in the preservation and protection of the mountain, terrestrial, and aquatic ecologies;
iv) Building capacities and increasing awareness among all stakeholders;
v) Institutional growth for biodiversity protection and conservation;
vi) Climate grids' identification and impact on forests and biological resources;
vii) Ecological research on land and water;
viii) Investigation of human involvement in ecological hotspots;
ix) Study of how the climate affects the timing of migratory bird movements;
x) Identification of the Himalayan ecosystem's present state and a study of climate trends for the Himalayan environment.

V. DELETERIOUS RAMIFICATIONS

Predictive risks experienced due to climate change will have major consequences for industries such as agriculture, water resources, and human health. Although the decrease in the number of frost days and an extension of the growing season may be beneficial to agriculture, however soaring temperatures and decreasing precipitation will result in increased water demands for irrigation. Teetering temperature and precipitation scenarios will exert a direct impact on water supplies and water-dependent systems. Dry spells are a new tendency in Kashmir's environment, with

exceptionally protracted dry periods occurring in recent years, causing severe water shortages. None of the 23 wells in Kashmir assessed for the May 2016 report had a water level moreover 20.0 meters below ground level, according to the Ground Water Year Book 2016-17. (m bgl). Water levels less than 2.0 m bgl have been recorded in 14 wells, according to the report, while the depth to the water level in seven wells ranges from 2 to 5 m bgl. One well showed water levels in the 5-10 m bgl range, and another well showed water levels in the 10-20 m bgl range." During the summer and autumn seasons, prolonged dry periods, as indicated by consecutive dry days, have an impact on surface water availability.

VI. CONCLUSION

Climate change is unambiguously a reality. It poses an unequivocal threat to the livelihood of people, biodiversity, water resources, agriculture, national growth, and political economies of nations on a global scale. It is characterized by the rise in global temperatures and the occurrence of extreme weather events such as heat waves, droughts, and floods. Kashmir Himalayas, nestled in a huge Himalayan belt, is considered to be a hotspot for climate change risk owing to its complicated topography, massive glacial and water resources, quick-responding watersheds with severe seasonality, and climate variability on a smaller scale. The present study was conducted with the prime objective of investigating the impact of climate change of impact of climate change on water resources in Kashmir. Climate change isn't Hailey's comet that will wake people from their carefree slumber after 75 years; rather it is akin to bacteria that grow speedily in space. Climate change is here to stay; therefore, it becomes imperative to prioritize and preserve biodiversity and address the climate change-based issues in Kashmir Himalayas. Climate change over mountainous basins demands a broader understanding of present and future temperature and precipitation regimes for better water resource management, hydropower generation, cryospheric resources, natural hazard risk assessment, and ecosystem response. The article calls for policy intervention in the future climate scenario of the Kashmir Himalayas. The changes in climatic conditions of the region will have serious ramifications in terms of water availability and the glacial environment of the Kashmir Himalayas.

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