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Assessing Water Demand And Supply For Srinagar City (J&K) India, Under Changing Climatic Scenarios Using Water Evaluation And Planning Model (WEAP)

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Abstract: *The study holds significance keeping in view the global climatic concerns, which began to cast their shadows on the climate of Jammu and Kashmir as well. In order to accomplish the present study, WEAP (water evaluation and planning model) of Stockholm Environment Institute was used. This model is a tool for integrated water resource management and planning like, forecasting water demand, supply, inflows, outflows, water use, reuse, water quality, priority areas and Hydropower generation, etc,. During the present study discharge data from 1979-2010 (past thirty years) of our study rivers i.e., Dachigam Stream and Sindh Stream was used as supply to our demand sites and also to find the impacts of changing climatic conditions over them. Due to availability of data upto year 2010 only therefore the scenarios were generated from year 2011 onwards. The water demands for Srinagar i,e., irrigation demands for agriculture and water supply demands for our domestic needs was analyzed, industrial demands were not analyzed as we have negligible demands in this sector. The water supplied to our demand sites was mostly contributed by our study rivers and a little demand was met by ground water. Data was collected from various agencies like PHE Srinagar, Census data of 2011, Meteorology department etc. This collected and generated data was given as input to the WEAP model. The model generated the trends for discharge of our study rivers for next 15 years and at the same time also generated scenarios calculating our demands and supplies for the future. The model results reveal that there will be shortages in the requirements met in the urban water needs for some years like 2016, 2017, 2018 and 2020. The results generated from the model outputs will help us in predicting whether our water resources are going to suffice our growing water needs or not in future. The results will help in drafting policies for future regarding water supplies and demands under changing climatic scenarios.*

Keywords: *Climate change scenarios, Demand sites, Discharge data, Global Climate Change, WEAP*

I. INTRODUCTION

The recent scientific assessment by the Intergovernmental Panel on Climate Change (IPCC) concludes that, since the late 19th century, anthropogenically induced emissions of gases such as carbon dioxide (CO2) that trap heat in the atmosphere in the manner of a greenhouse have contributed to an increase in global mean surface air temperatures of about 0.3 to 0.6^0 C. Moreover, based on the IPCC's mid-range scenario of future greenhouse gas emissions and aerosols and their best estimate of climate sensitivity, a further increase of 2^0 C is expected by the year 2100 [1]. The purpose of this paper is to examine the likely impacts of a Climate change on the supply and demand for water and the resulting socioeconomic implications.. The consequences of these global climatic changes are already being witnessed in several Himalayan areas where glaciers and glacial lakes are changing at alarming rates. Climate change is affecting the temperatures, amount of snow and ice in the Himalayan region as well as rainfall patterns [2]. Due to global warming, the Indo-Gangetic basin of the Indian subcontinent, where water supply is dominated by melting snow and glacier ice, will be faced with severe environmental problems. Negative impacts, including seasonal shifts in water supply, flood risks and increased precipitation variability, will eventually offset benefits incurred by short term increases in runoff from glacier melt [3]. According to Dr Shakeel Ramshoo, convener of the Climate Change Research working group of

Kashmir University, the Kolahai glacier has been melting at the rate of about 80 sq m per year over the last three decades since 1976 and has shrunk from 13.87 sq km to 11.24 sq km. Situated at an altitude of 3600 m, the Kolahai is the source of water for Lidder and Sindh, two major fresh water streams in the Jhelum basin. Dr Ramshoo says that the melting is due to the climate change, "The increase in the Kashmir temperature has been 1°C, which is much more than the 0.72°C rise in global temperature over the past century. The result is less snowfall and less formation of glaciers."[4] Keeping in view the decreasing water supplies and increasing demands in Kashmir valley in general and Srinagar district in particular the current study holds great significance as our domestic water demands are increasing with the increase in the population and standard of living of the people with each passing day.

In order to prepare for future in advance, an attempt was made to calculate our water demands and the supply which we have at present, the trends and climatic scenarios of water demands and supply were drawn from WEAP Model, of Stockholm Environment Institute. WEAP Model is a microcomputer tool for integrated water resources management and planning. It provides a comprehensive, flexible and user-friendly framework for policy analysis [5]. Operating on the basic principle of water balance accounting, WEAP is applicable to municipal and agricultural systems, single sub-basins or complex river systems [6]. In the present study following objectives were accomplished analyzing the trends in the discharge data of our study rivers, evaluation of water resources available to Srinagar city, evaluating all water demands and supplies, and to manage the water resources in accordance to changing climate scenarios.

II. STUDY AREA

Srinagar lies between the coordinates 34^0 01' N to 34^0 27`N latitude and 74^0 36' E to 75^0 30' E, it is around 77 km long and 40 km wide, the average elevation of the valley is 1600 m above sea level spread over an area of 1862 sq km located approximately 1730 m above the sea level. Srinagar is surrounded by Budgam district in the west, Pulwama in South and Ganderbal in north. The valley of Jammu & Kashmir as a whole is an asymmetrical fertile basin, stretching from south-east to north-westerly direction. Its diagonal length (from SE to SW corner) is 187 km ,while the breadth varies considerably, being 115.6 km along the latitude of Srinagar, the altitude of the floor of valley at Srinagar is 1600 m and the highest peak among its surrounding mountains is that of the Kolahoi or Kwashiorkor (Alt.5420m).

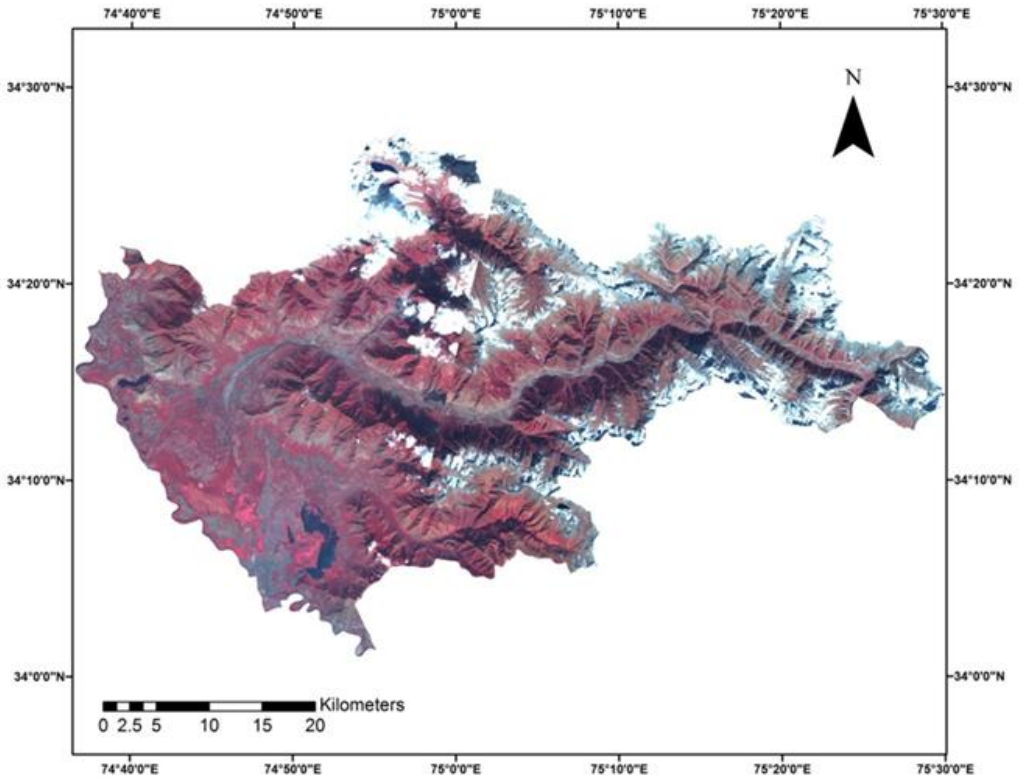

Figure 1: Location of Study Area.

III. METHODOLOGY

The methodology that was employed for current research involved use of satellite/remote sensing data in a GIS environment combined with field investigation, hydrological data, digital elevation data, secondary/ancillary data, and simulation modeling. The study relied on two fold methodologies wherein firstly the necessary datasets required to simulate future climatic scenarios were generated and later these generated datasets were given as input to WEAP Model. Detailed methodology consisting of schematic flow chart of the methods used to address the research objectives is shown in Fig.2 below:

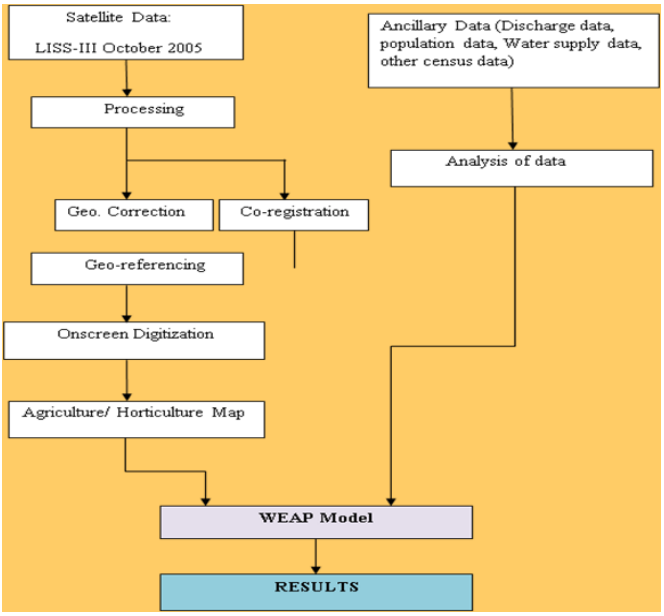

Figure 2: Methodology Flowchart

LISS III image of October 2005 was geometrically corrected and registered using ERDAS IMAGINE 8.4 software. Arc view 3.2 software was used for on-screen digitization. At the same time other data related to the study area viz: ancillary data like census data of 2011, Ground water potential and its usage, PHE water supply data and discharge data of study rivers was preprocessed and analysed and then put as input to WEAP Model to generate the final results.

IV. RESULTS & DISCUSSIONS

The basic datasets to generate the model results were generated firstly by analyzing the discharge data of our three demand sites viz: Dachigam Stream, Sindh Stream and Srinagar city from (1979- 2010). From the analysis of discharge data of each demand site individually it was found that mean yearly discharge and monthly data of Dachigam Stream from 1979- 2010 showed an overall decreasing discharge trend or negative trend, depicting that the discharge in the river is decreasing. Maximum discharge was observed for year 1981and for year 1999 lowest discharge was observed.

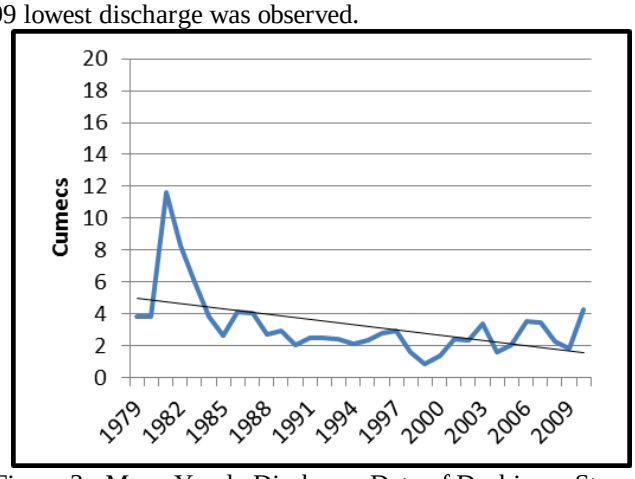

Figure 3: Mean Yearly Discharge Data of Dachigam Stream

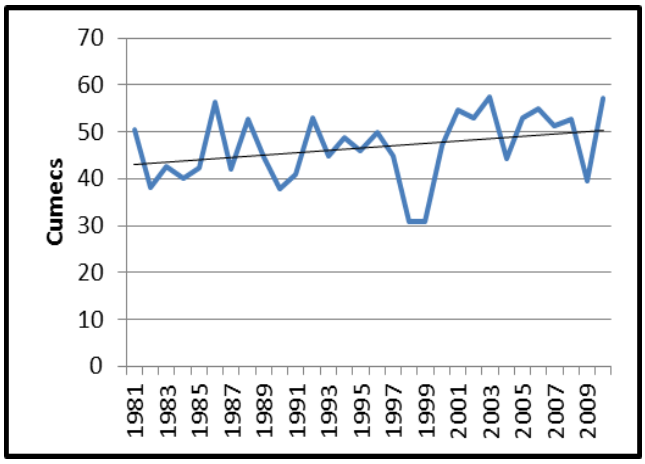

Figure 4: Mean Yearly Discharge Data of Sindh Stream

The results of analysis for Dachigam Stream showing average mean yearly discharge is shown in the Fig. 3. The months June, July, August are of much significance as the demand is increased due to irrigation needs for rice cultivation. The discharge trends for these months are decreasing in the same manner as the yearly discharge trends show decreasing trends. In case of Sindh Stream it was found that overall discharge over the past years is increasing, the reason may be attributed to fast melting of glaciers [3].

1. Domestic Water demands: It was found that Srinagar City has a population of 1269751 (2011 census). 98% of the population uses Tap water (2011 census). Water usage per person is about 111 m3/yr or 304 L/day (100 m^3 from tap water and 11 m^3 from ground water - PHE Srinagar). 79 MGD of water are supplied to 1.27 million people in the city from PHE supply and 1.58 MGD is harnessed from ground water. This accounts for 299 L/day/person of the water supplied from PHE supply and 5.9 L/day/person for the supply from the ground water and other sources. Water consumption per capita is much higher in Srinagar than the overall average in India, as J&K state is rich in water resources and tap water supply is available 24x7.
2. Irrigation Water Demands: Total area irrigated by Dachigam stream was found to be about 2300 hectares and the abundant crop was paddy, Minimum Water demand per hectare = 3,000 m^3 (SKUAST). Rate of change of agriculture to horticulture/urban was found to be 18% per decade from the analysis of past satellite data. Present water demand for agriculture is found to be 12 Million Cubic Meters. Present agriculture is 1205 hectares and accordingly it will be left to 917 ha in 2026. In case of overflowing the paddy fields demand per hectare is 10,000 m^3. About 45% of water is consumed in the first month for sowing and transplanting i.e., Ist stage of paddy growth [7].
3. Water Demand and Supply Analysis for Agriculture Sindh: Total area under paddy cultivation = 10000 hectares. Water demand for Sindh agriculture was found to be 101.7 Million Cubic Meters. Sindh has large discharges rates and the volume that is available is able to satisfy the demand fully for agriculture.

4.1 Model Results

The various parameters which were fed to WEAP model in order to generate various simulations were, census data (2011) PHE (Public Health Engineering data to see overall water supply to Srinagar, discharge data of past 30 years (1979-2010), total agricultural land to see agricultural demands, water requirements per hectare in our demand sites was found from Sher-I-Kashmir University of Agricultural Technology (SKUAST). All the data was compiled and brought in the format acceptable to model and the model simulations were run for 16 years. Fig below shows the overall results generated by the model in the form of overall inflows, outflows from the rivers, supply requirements and the un-met demands for the three demand sites for the city of Srinagar. It includes four water nodes for inflows i.e., Dachigam Stream, Jhelum River, Sindh Stream and the ground water. From these nodes water is supplied to demand sites. The Outflows from Areas includes the water that comes out of the demand sites when their needs are fulfilled. The Supply requirements are generated for three demand sites that include Domestic water demands for Srinagar City, Irrigation water demands for Dachigam agriculture and Sindh agriculture. The next scenario generated was for Unmet water demands in thousand meter cube for three demand sites.

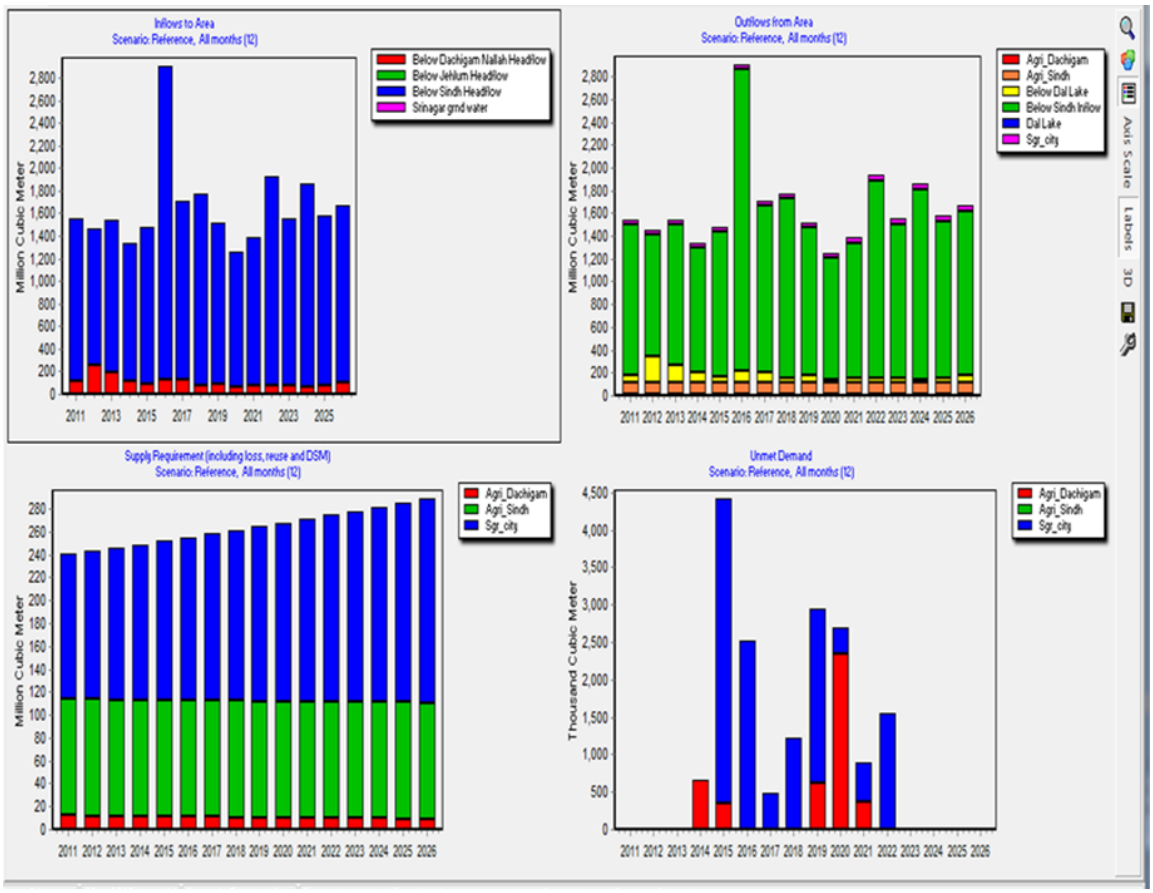

Figure 5: The Overall Results Generated by The Model Upto Year 2026

4.1.1 Discharge Trend

The Discharge trend that was generated by WEAP model is based on the previous discharge trend, of thirty years that was given as input to the model. High discharge years as simulated by model are 2016 for river Sindh and 2012 for Dachigam Stream, probably due to fast melting of glaciers due to global warming, whereas low discharge years as simulated by the model were 2026 for River Sindh and 2015,2016, 2018, 2020, probably because of shrinkage of glacier areas.

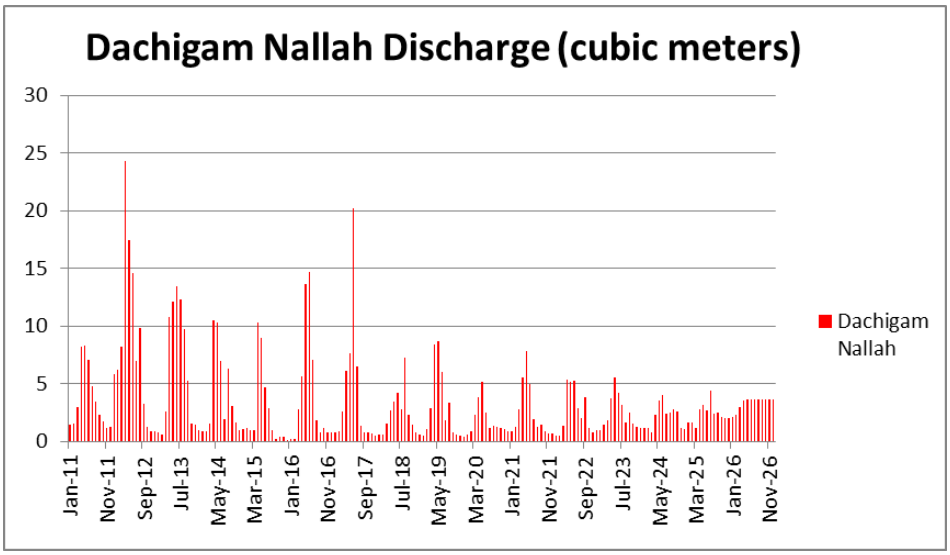

Figure 6: Discharge Data for Dachigam Stream 2011-2026 as generated by Model.

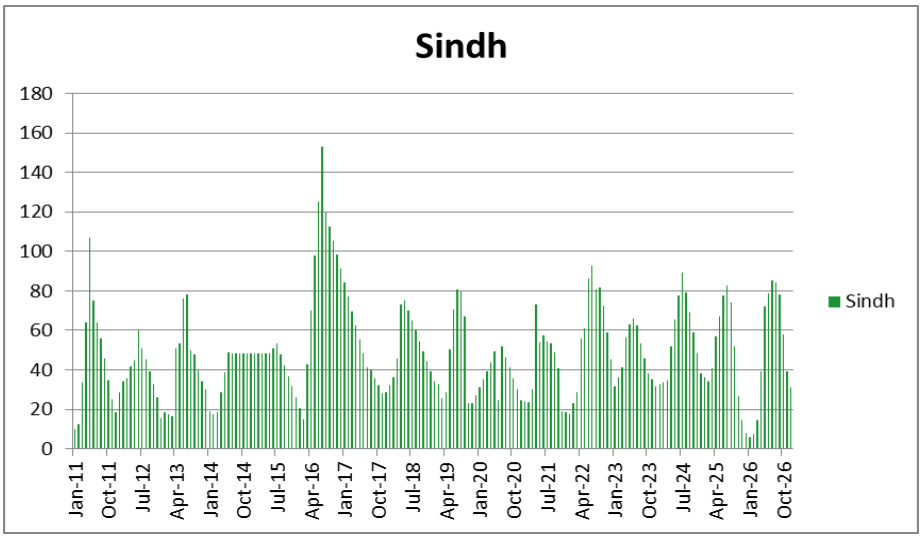

Figure 7: Discharge Data for Sindh Stream 2011-2026 as generated by Model

4.1.2 Supply Requirement

WEAP Model has generated the water requirement for three demand sites for next 15 years. It is evident from the table that water requirements for Srinagar city increase from (127-176) Million cubic meters from 2011 to 2026. The demand for Srinagar city is increasing due to increasing population and urbanization, whereas the demand for Agriculture Dachigam is decreasing (12-9.1) Million cubic meters, due to conversion of agriculture land to horticulture and urbanization. The demand for Sindh agriculture is constant due to no changes in the area of agriculture land.

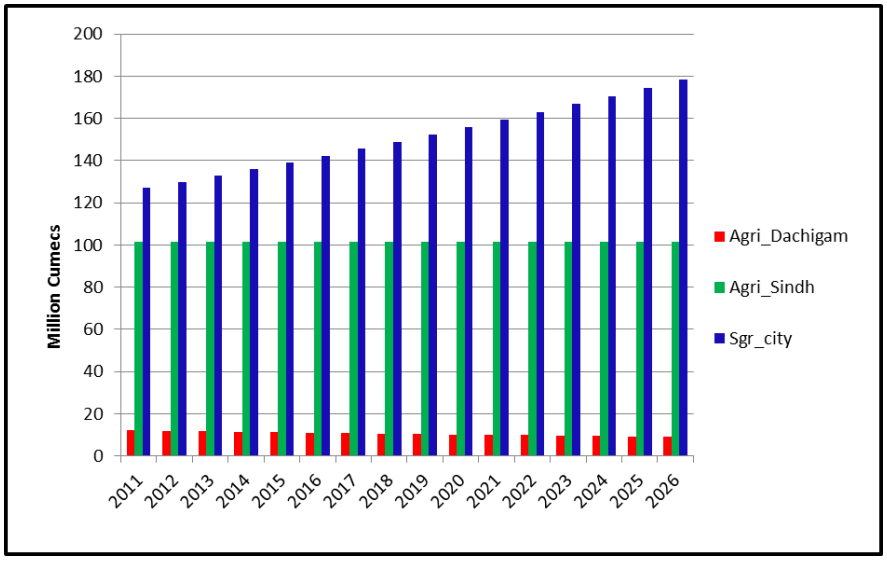

Figure 8: Water Supply Requirements for Srinagar City in Million Cubic Meters (Model Results)

4.1.3 Supply delivered

Supply delivered to the demand sites is shown below in the table. Supply delivered to the demand sites is varying as is prevalent from the model results above, it is delivered 100% in some years while as in some years there is shortage of the supply. In some years there is reduced discharge in the study rivers as analyzed by the study, which affects the supply.

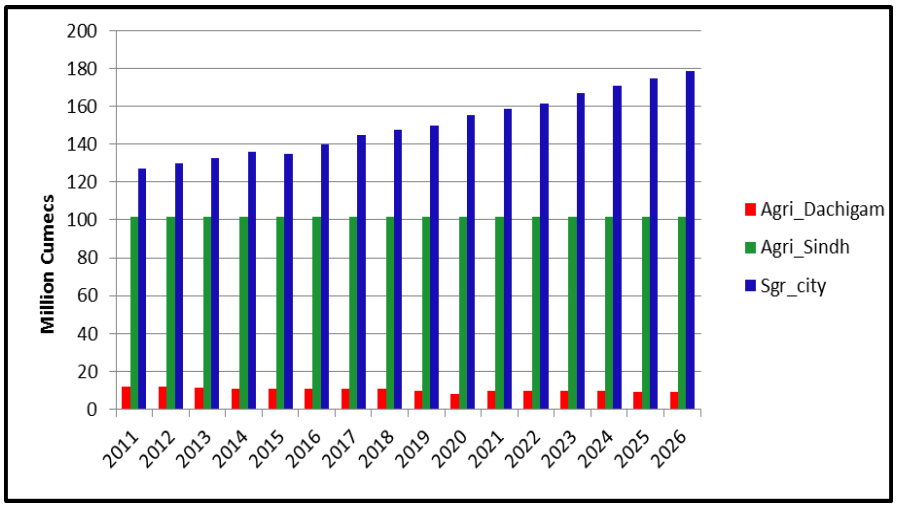

Figure 9: Water Supply delivered to the demand sites (Million cubic meters).

4.1.4 Un-Met water Demands

The figure below shows the results of unmet demands for three demand sites from 2012-2026, generated from WEAP model. On the basis of results generated it was found out that Srinagar city has an un-met demand of almost 4 Million meter cube for the year of 2015 while as Agriculture Dachigam has a shortage of almost 3 Million meter cube. The un-met water demands are shown in Figure 10.

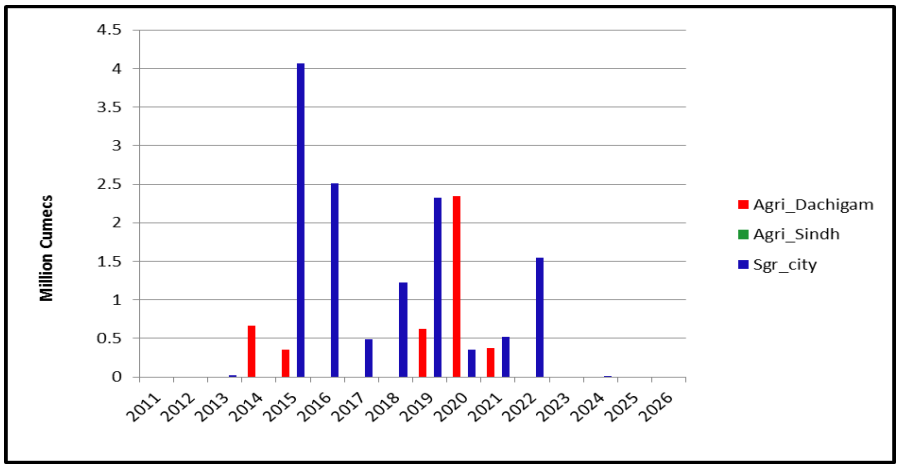

Figure 10: Un-met Water Demands (Thousand Cubic Meters

Site Reliablity:

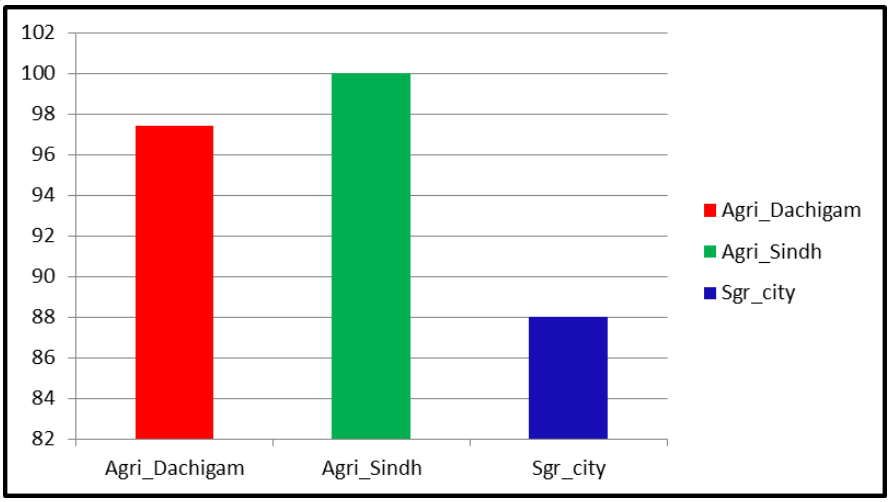

Figure 11: Site Reliability for The Demand Sites

It shows that Agriculture Sindh has 100% reliable site i.e., its demands are fully fulfilled. While as the water sources that fulfill the demands of the Srinagar city are only 88% reliable. 12% of the demands are not fulfilled.

V. CONCLUSION

On the basis of the results formulated from the current study, following main conclusions can be drawn:

1. Discharge data analysis for the Dachigam stream revealed that the flow has decreased from 1979-2010.
2. Agriculture demands for Dachigam area are facing shortage even in minimum requirement scenario because of reduction of almost 10 times discharge from the year of 1979-2010 in the Dachigam stream. Agriculture Dachigam faces shortage mostly in the month of July. In order to meet the domestic water needs, the Dachigam Stream fed agriculture must be irrigated efficiently.
3. Dachigam fails to provide even 15% of the water supplied to Srinagar City. On the contrary discharge data analysis for the Sindh stream revealed that the flow has increased from 1979-2010. Therefore Sindh Stream has the potential to meet the growing water demands of Srinagar city.
4. From the WEAP model predictions, it is assumed that urban water supply met to city will be only 85% in 2016 and 90-95% in 2017-2019 and 2022.
5. It is also predicted that the urban water supply met to city will likely to face shortage in winter months.

VI. RECOMMENDATIONS

From the analysis of the results, it is found that Sindh stream has the potential of meeting the growing demands of water supply to Srinagar city in future, therefore judicious use of water from Sindh stream and restoration of this water stream by checking the illegal encroachments along its course is necessary. It is also recommended to make water storage reservoirs at various places along this stream, so as to store the water for meeting the demands of water during the winter months to the Srinagar city.

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