CLIMATE CHANGE AND WATER MANAGEMENT OF SINDH CATCHMENT

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ABSTRACT

The Sindh Catchment located in Ganderbal district of Jammu and Kashmir, India is one of the most important water resources. It is one of the main tributaries of the river Jhelum in the valley of Kashmir. It boosts the economy of the valley, through generation of hydroelectricity, irrigation for agriculture and tourism because of snow covered mountains which surround the valleys. Therefore, in the current study of Sindh discharge were assessed using a WEAP model, GIS tools and satellite images to determine the effect of climate change and to calculate present and future water demands under different scenarios for a modelling period from 2020 to 2030. The river Sindh is a perennial river and main source of of the river lies in the Machoi Glacier which is at an elevation of 4800m, east of the Amarnath temple and south of the Zoji La as due to global warming Himalayan glaciers are melting at an alarming rate to know the changes in glacier cover with time satellite images and meteorological data are used. The satellite images have revealed that due to global warming snow cover has been decreased. Because of changing weather pattern higher discharges are present in summer season and in winters there is shortage of water due to very low temperature water freezes, which affects demand in winters and there are also higher chances of flood in summer season.

INTRODUCTION

Glaciers are one of the most important resources of nature with greater importance as a perennial source of freshwater, hydropower generation and regional climatology. However, the climate change has impacted the cryosphere with the consequent impacts on streamflow, food production and even tourism (Slingo et al. 2005; Scott et al. 2012; Dar et al. 2014; Romshoo et al. 2015). The hydrological regimes are continuously experiencing the changes and will experience further changes in the future under changing climate scenarios (Brunner et al. 2019; Jasrotia et al. 2021). Therefore, it is necessary to access future streamflow changes is vital as it will guide in the improved water resources management practices (Jasrotia et al. 2021). Studies have revealed that climate change can affect the hydrological systems adversely. However, these impacts on hydrologic systems may vary from region to region (IPCC 2007; Chu et al. 2010; Khattak et al. 2011; Zhang et al. 2011; IPCC2013). The ecological and commercial growth of a region are greatly affected by the hydrological systems. The physical features of the basin, climatic conditions, and human activities together affect the hydrologic cycle of a basin (Mahmood and Jia 2016). Temperature, precipitation, and evaporation are the major focus of the researchers (Wang et al. 2012; Mahmood and Jia 2016) as these factors are considered to be the symbolic parameters affecting the variability of a river basin. The world's average surface temperature has increased between 0.3 and 0.6 °C over the past hundred years (IPCC 1992; Bajracharya et al. 2008), and the increase in global temperature is predicted to rise continuously during the current century (Bhutiyani et al. 2007; Romshoo & Rashid 2012; Rashid et al. 2015). The temperature rise has resulted in the shrinkage of most glaciers and ice caps all around the world (Sorg et al. 2012). Analysis of the glacier response to the climate change leads to an understanding of the mechanism of glacier fluctuations (Dyurgerov & Meier 2000; Anderson et al. 2008).

In Non-Polar Regions, Himalayan glaciers form one of the largest concentrations of ice. Himalayan glaciers constitute an important proportion of freshwater of the major river systems of the Asia such as Indus, Brahmaputra and Ganges. The climate of the Himalayas is highly variable because of its wide range of geographical factors that contribute to variations in temperature and precipitation (Young & Hewitt 1990). Average temperatures are predicted to rise between 3.5 °C and 5.5 °C by 2100 in the Indian sub-continent (Lal 2002) and by 6.43 °C (±1.72) in the Kashmir Himalayas (Rashid et al. 2015). The most immediate impact of this rise in temperature will adversely affect the glacier recession rate in the Himalayas, because of the sensitivity of cryosphere to temperature changes (Hasnain 2008; Bhambri et al. 2011).

The objective of this research was to study of variation of Sindh River discharge under climate change and demand analysis for a modelling period of 10 years.

STUDY AREA

The Sindh Catchment is located in Ganderbal district of Jammu and Kashmir giving passage to a Sindh River whose source lies in the Machoi Glacier which is at an elevation of 4800m, east of the Amarnath temple and south of the Zoji La and is situated between geographical coordinates of latitude 34.216496, and the longitude 74.771942. The length of the Sindh River is 116 km and consists of about 1683 km2 of the basin area. Alongside the river, there are three hydropower plants currently operating and producing electricity. River is one of important tributaries of river Jhelum. It is the only river in Jammu and Kashmir on which three hydroelectric power plants are operated besides agriculture and domestic demand, which adds to its significance.

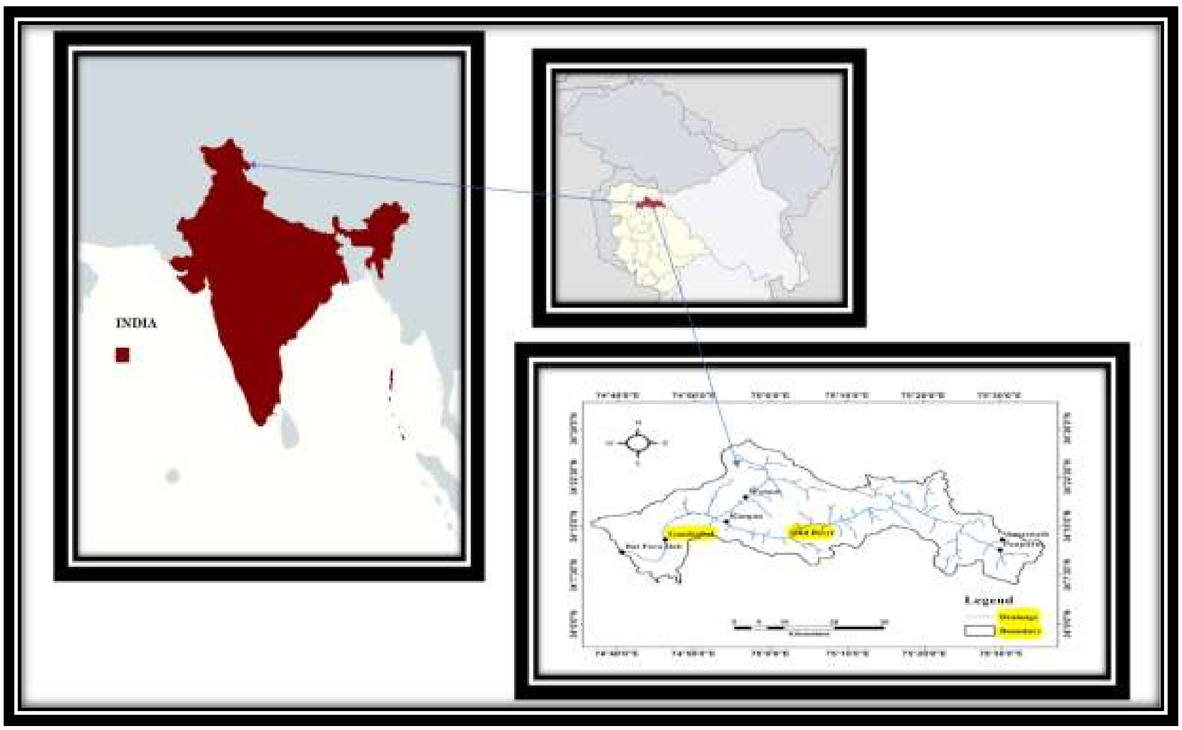

Fig. 1 : Study area map of Sindh River Prepared in QGIS Software using DEM Data collected from USGS (https://earthexplorer.usgs.gov/)

DESCRIPTION OF DATA

The daily discharge data for the Sindh River were obtained from Irrigation and Flood Control Department of J&K, India. The discharge data were collected from the gauge stations of the Sindh Valley watershed, i.e., Dodarhama from1996-AUG 2020. Daily temperature (maximum temperature and minimum temperature) and rainfall for 25 years (1992–2017) were collected from the IMD, Meteorologic 2011 Census, PHE and Jammu and Kashmir UT Water Resource Regulatory Authority al Centre, Srinagar. The data of human population and water demand data was collected from PHE, Jammu and Kashmir. Agricultural data of irrigated land and water requirement data was collected from Directorate of Agriculture, Kashmir (Srinagar) and Agromet Field unit, SKUAST-K. The data for hydropower discharge demand was collected from JKPDC Srinagar. Data for DEM of study area was collected from USGS (https://earthexplorer.usgs.gov/) and data for satellite images was collected from PlanetScope (https://www.planet.com/products/planet-imagery/).

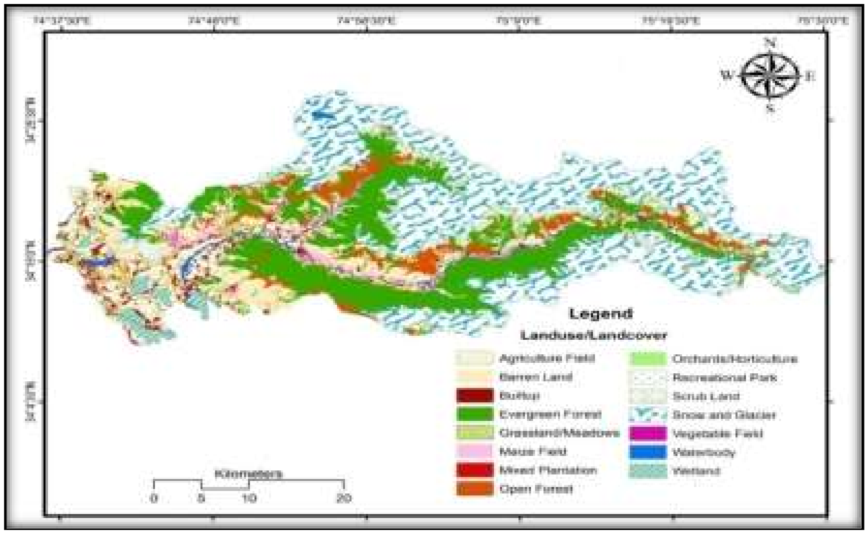

Fig. 2 : Land map use of study area, Source: SKAUST-K (https://www.skuastkashmir.ac.in/)

Table 1 : Area irrigated in Kashmir region by division and district wise, in thousand hectare (2020 cropping year), *Source* : Directorate of Agriculture, Kashmir (https://www.skuastkashmir.ac.in/)

S. N.	Division	Districts	Area irrigated (in '000 ha)						
			Paddy	**Maize**	**Vegetables (Kharif)**	**Other cereals**	**Vegetables (Rabi)**	**Apple and Pear**	**Total**
1	Southern Kashmir	Anantnag	24.50	2.24	2.64	2.74	2.67	11.39	46.18
		Kulgam	16.00	0.81	1.78	1.76	1.80	11.24	33.39
		Pulwama	16.50	0.63	3.00	2.59	3.00	10.13	35.85
		Shopian	0.56	0.22	0.53	0.63	0.53	13.24	15.71
		Sub-total	**57.56**	**3.90**	**7.94**	**7.72**	**7.99**	**46.00**	**131.11**
2	Central Kashmir	Srinagar	2.65	0.09	2.50	0.88	2.50	1.22	9.84
		Ganderbal	8.60	0.66	1.10	2.08	1.10	4.72	18.26
		Budgam	25.00	1.95	3.38	2.51	3.40	9.61	45.85
		Sub-total	**36.25**	**2.69**	**6.98**	**5.47**	**7.00**	**15.56**	**73.95**
3	Northern Kashmir	Bandipora	9.99	0.72	1.98	2.26	1.80	3.12	19.87
		Kupwara	17.00	2.40	2.98	2.94	1.50	11.95	38.77
		Baramulla	20.56	2.40	2.68	2.44	2.70	15.58	46.36
		Sub-total	**47.55**	**5.52**	**7.63**	**7.64**	**6.00**	**30.66**	**105**
Grand Total			**141.36**	**12.11**	**22.54**	**20.83**	**20.99**	**92.21**	**310.44**

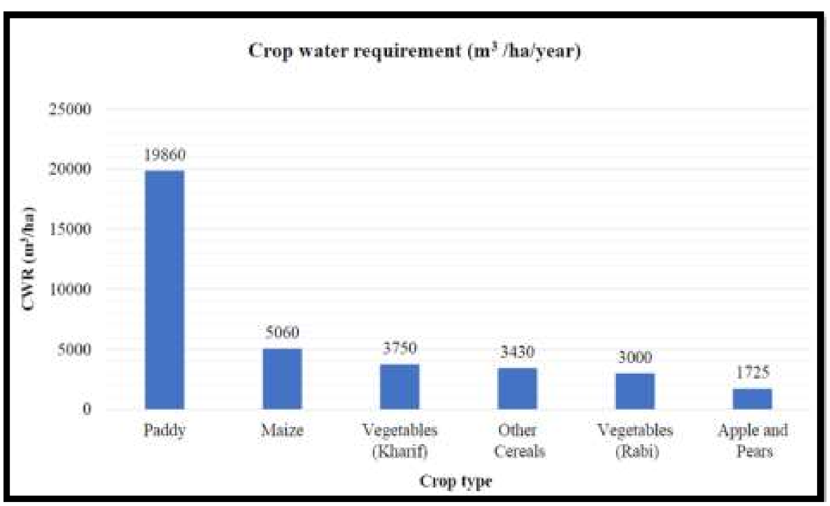

Fig. 3 : Agricultural Crop water requirements of different crops of Kashmir Valley, Source SKUAST-K (https://www.skuastkashmir.ac.in/)

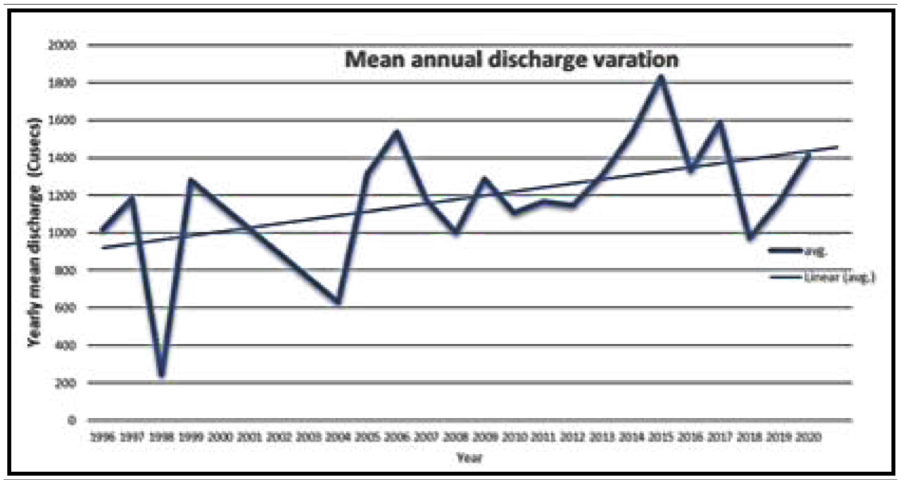

Fig. 4 : Mean annual discharge variation of Sindh Catchment, Source: Kashmir Irrigation & Flood Control Department Srinagar (https://www.ifckashmir.com/)

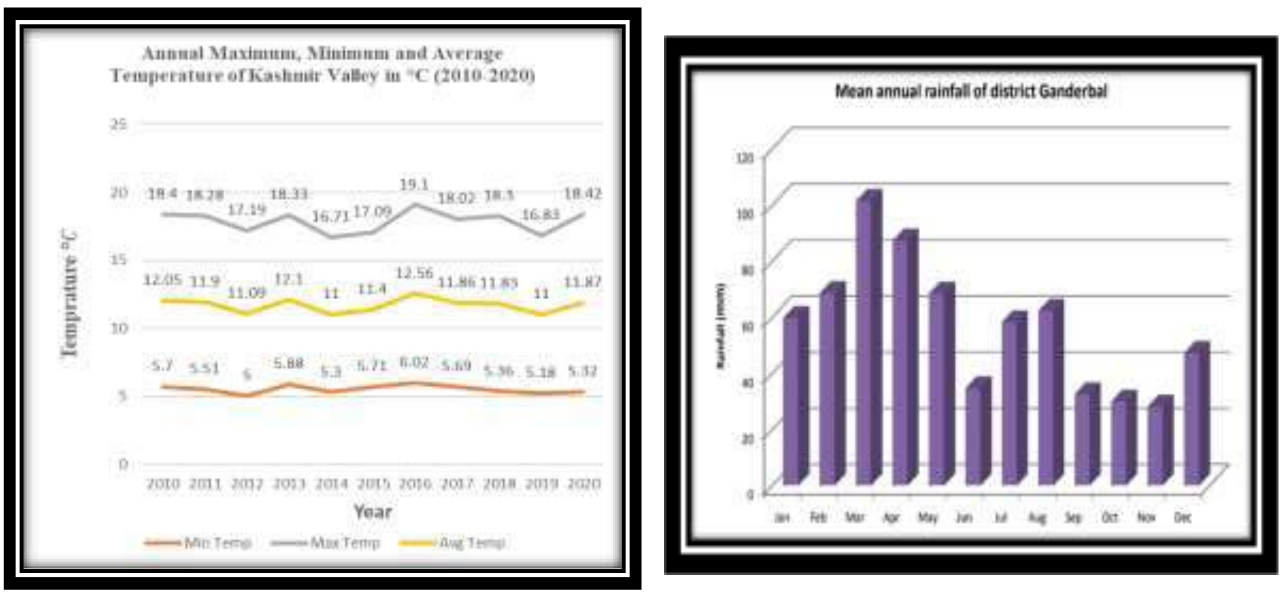

Fig. 5 : Variation of Temperature and Rainfall with time in Kashmir Valley and study area respectively, Source, Meteorological Centre, Srinagar (https://mausam.imd.gov.in/srinagar/)

METHODOLOGY

Water Evaluation and Planning system was developed by the Stockholm Environment Institute (SEI). Windows-based decision support system for integrated water resources management and policy analysis. WEAP is a unique water resources and planning software where it simulates hydrologic pattern based on climatic inputs such as precipitation, temperature, humidity, and wind speed. QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. QGIS can display multiple layers containing different sources or depictions of sources. Used QGIS Software to derive shapefile of Sindh River Catchment. With the help of shapefile sketch of the model was prepared in WEAP for a modelling period from 2020 to 2022. Discharge data and demand data are entered into WEAP model of Sindh Catchment using template files and results are viewed under different types of scenarios like equal priority, normal population growth, higher population growth, priority one for domestic demand and results are viewed in tabular as well as in chart form. Variation of snow cover due to climate change is observed by using satellite images of different years in same month and of same location.

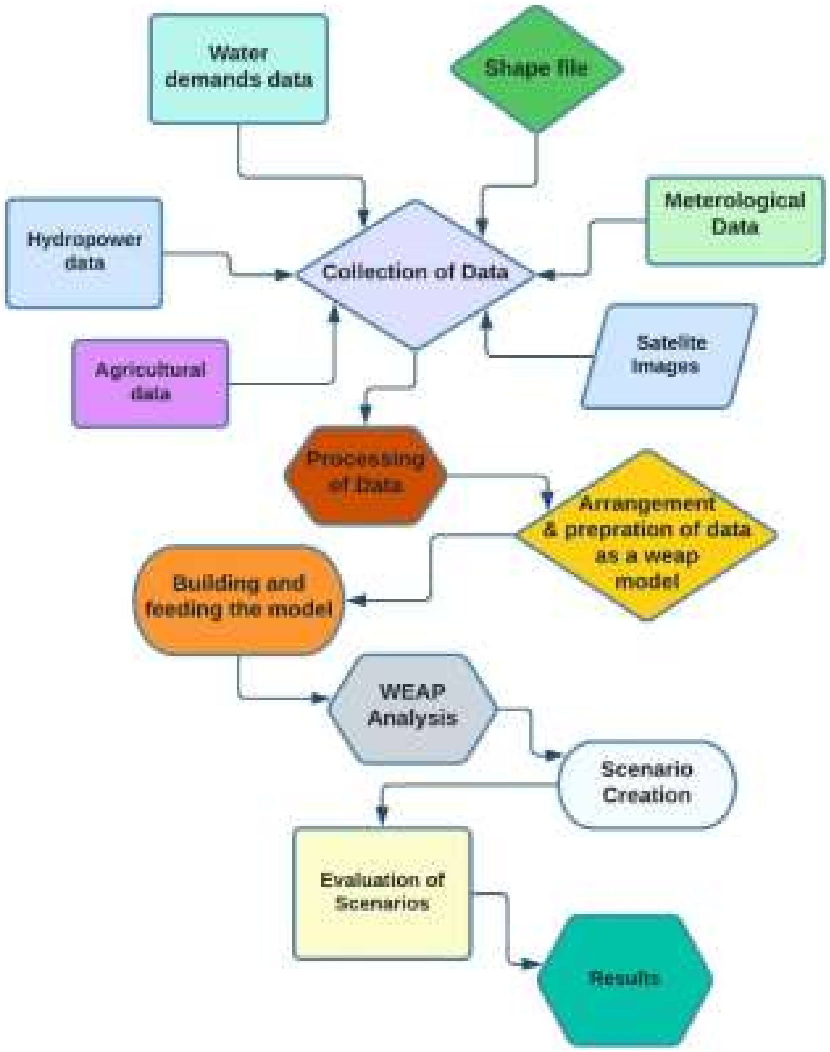

Fig. 6 : Methodology flow chart

RESULTS AND DISCUSSION

Climate Change is in itself a complex parameter which directly indirectly independently depends on various parameters so in order to observe the changes caused by global warming satellite images are used of two different times but of same location area. In my case I have chosen two satellite images one of June 2017 and another one of June 2021 as shown in figure 5. The red area represents sensitive areas which have been affected with time after clearly observing these images its revealed that snow cover has been decreased with time which is also responsible for higher discharges with time. As it was also reported by (ICIMOD) International Centre for Integrated Mountain Development was conducted for Hindukush Mountains. As per a report it was said global warming is increasing and in non-polar regions 2/3 of glaciers will melt by 2021. As per the report it was also said that melting of glaciers is going to affect 2 billion people.

Mean multiannual monthly discharge was used for a modelling period of ten years. Also, model has a different kind of demands domestic demand, agricultural demand and hydropower demand. When model was run under different scenarios different kind of results are generated. In case of high population growth and keeping priority one for domestic demand results are generated as shown in figure 6 (d) which shows there is shortage of water in months of January, February, March, November and December due to freezing of glaciers and most affected is power plant because of low discharge available as shown in Table 2.

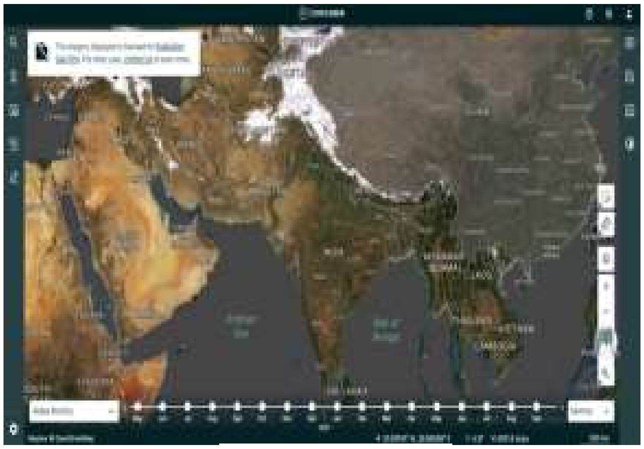

Fig.5 (a)

Fig.5 (b)

Fig.5 (c)

Fig.5 (d)

Fig.5 (e)

Fig.5 (f)

Fig. 7 : Observing effect of global warming on Himalayan glaciers using satellite images, Source: PlanetScope (https://www.planet.com/products/planet-imagery/)

Table 2 : Results in tabular form generated by WEAP Software of unmet demand in cubic meter under scenario priority one for domestic demand.

Unmet Demand (Cubic Meter)

All Demand Sites, Scenario: Priority 1 domestic demand, All months (12), Monthly Average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Agriculture	0	0	100180	0	0	0	0	0	0	0	0	0	100180
Domestic Demand	348420	272827	55251.7	0	0	0	0	0	0	0	127780	278444	1082724
Powerplant	16856202	11984593	3702129	0	0	0	0	0	0	0	6152154	13476698	52171776
Sum	17204622	12257420	3857560	0	0	0	0	0	0	0	6279935	13755142	53354679

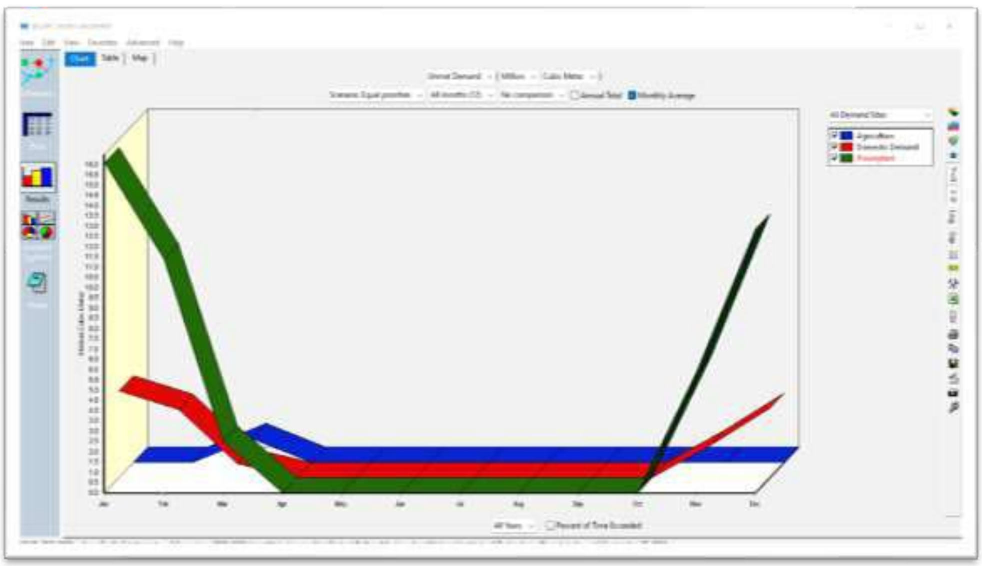

Fig. 8 : Result generated in WEAP Software for unmet demand in 3d View for Agriculture, Domestic demand, Powerplant.

CONCLUSION

The most of the India population is dependent on the climate sensitive sectors like agriculture and forestry and water is the key factor for agriculture. India is considered vulnerable to the climate change and its socio-economic effects. There are also vast sectoral and regional variabilities in India that affect the adaptive capacity of the country to climate change (Roy et al. 2013; Bhatt and Sharma 2002). Assessment of water resources is a major requisite for planning of long-term sustainable management policy for water to combat this situation.

In this study of Sindh Catchment WEAP model it was clear discharge is varying monthly as well as annually and its showing positive trend because of global warming melting of glaciers is accelerated in Himalayan regions which will result in frequent and flush floods which will affect the economy as well as lives of people and in long run if climatic condition still get more worse that will result in shortage of water in Himalayan glacier dependent rivers. This study can benefit the managers of water resources to choose the most appropriate model for studying the climate change impact on flow regimes of the study area (Sindh River Catchment).

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