Overview of the various factors impacting the distribution of river water of Punjab, India

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Abstract: Surface water bodies are one of the major sources of fresh water and also a matter of dispute among the territories sharing their water. Similar situation has been faced by Punjab, India, through which three rivers of Indus river system i.e., Ravi, Beas and Satluj passes. This article presents the various factors that need to be considered before distributing the water of the rivers of Punjab among neighboring states and countries. This article highlighted that the major factors that should be considered are, precipitation, snow fall, glacier retreat, demography, irrigation pattern, groundwater level, hydro-electricity and flooding. Further, the data from previous years for each factor has also been discussed so that any timely change in these factors could be highlighted. In this way, it was illustrated that distribution of river water should be based on the current scenario of the previously mentioned factors. The discussion made in this article may assist the policy makers in making a comprehensive analysis of the situation before distributing the river water of Punjab, India.

Keywords: Fresh water, sustainable development, renewable energy, developing countries, glacier retreat.

1. Introduction

Fresh water is one of the important requirements for the sustenance of the mankind. On Earth, the proportion of fresh water is approximately 2.5% out of the total available water and it is available in different forms i.e., snow, ice, groundwater and surface water. Among the various forms of freshwater, the most accessible to the humans is the surface water [1–3]. Therefore, civilizations are generally built around the rivers as they fulfill the various needs of agricultural activities, industrial activities, domestic usage etc.

In current times and also in history, the distribution of river water among the different territories has been observed as a cause of several disputes. Similar situation was faced while distribution of water of the Indus system of rivers among India and Pakistan after their partition. The Indus system of rivers comprise two types of rivers i.e., 1) Western comprising Jhelum, Chenab and Indus, 2) Eastern comprising Ravi,
Beas and Satluj [4]. After long contemplations and interventions, this dispute was solved by the Indus Water Treaty of 1960 and the distribution of Eastern rivers in Punjab was done as shown in Figure 1.

![Illustration of Punjab's Dams and canal systems](https://irrigationapp.punjab.gov.in/Login.aspx?type=canal)

**Figure 1.** Illustration of Punjab's Dams and canal systems (source: https://irrigationapp.punjab.gov.in/Login.aspx?type=canal)

As per the Indus Water Treaty, India may utilize the 34.34 MAF of the water flowing in three Eastern rivers of Indus River system i.e., Ravi, Beas and Satluj, all of which fall in Punjab state of India. Therefore, authorities of Punjab, India, started framing policies considering the various demographic and geo-political situations of just-independent India. Owing to those policies, several dams such as, Bhakra Dam, Pong Dam, Pando Dam etc., barrages/headworks such as, Harike headworks, Madhopur headworks, Ropar headworks etc., and canal systems were constructed on the Eastern rivers. Also, certain policies were also framed to provide river water to neighboring states i.e., Rajasthan, Jammu & Kashmir and Haryana, some of which such as, construction of Indira Gandhi Canal, transferring water from the Harike headworks to Rajasthan, has been completed. However, others have caused inter-state disputes such as, the issue of Satluj-Yamuna Link canal between Punjab and Haryana States of India [5–7].

Peaceful distribution of surface water among the different territories is a matter of engineering so that a comprehensive understanding of the matter can be made. In this regard, it is crucial to contemplate the various factors that could impact the flow of fresh water in the surface water bodies and their impact on the demography of different territories [8–11]. Therefore, this article presents an insight of the various factors that should be considered while further distribution of the Eastern rivers' fresh water among the neighboring states of Punjab, India.
Figure 2. Delineating the various factors impacting the distribution of river water in Punjab, India

2.1. Climatic changes

2.1.1. Precipitation

Precipitation is one of the modes via which the fresh water of rivers is recharged. On the basis of the annual rainfall of the last 114 years [12–14], Punjab state has been categorized into three segments and these are as follows:

a. North East zone (Precipitation 862 to 1028 mm): Pathankot, Gurdaspur, Hoshiarpur, SBS Nagar and Rupnagar
b. Central zone (Precipitation: 451 – 725 mm): Amritsar, Kapurthala, Jalandhar, Ludhiana, Fatehgarh sahib, SAS Nagar, Patiala, Sangrur, Barnala, Moga, Faridkot and Tarn Taran
c. South West zone (Precipitation: 355 – 400 mm): Firozepur, Fazilka, Muktsar, Bathinda, Mansa.

The monsoon rainfall i.e., during the months of June, July, August and September, contributes the maximum to annual rainfall amounting to approximately 78.3% for Punjab State. Contribution for pre-monsoon (March, April and May) rainfall on an average is 8.3%, contribution of post-monsoon (October, November and December) rainfall is annual rainfall is about 5.5% and winter rainfall (January and February) contribution is 8%. For the period of 1951-2013, annual rainfall shows negative trend for Punjab State (IMD 2017). Average annual seasonal rainfall over Punjab for the years 2012 to 2017, is shown in Figure 3.
The average rainfall during the monsoon periods between 2013 to 2017 is 347 mm i.e., 74% of the annual average rain. Average annual rainfall in Punjab based upon base period of 1951-2000 was 636 mm. Average annual rainfall in Punjab based upon period of 1961-2010 is 597.4 mm, with decrease of 39 mm of rainfall. Evaporation in Indo-Gangetic plains including Punjab varies from 150-250 mm [15–18] (IMD 2019).

2.1.2. Snow fall and glacier retreat

The origin of the three rivers and their tributaries, flowing in Punjab, is either the snow or the glaciers located in the Himalayas. However, due to climate change and increased global temperature, several studies have reported a gradual decrease in the snow fall over the Himalayas and also the retreat of the Himalayan glaciers. In an GIS-based analysis done Sood et al. (2020), it was estimated that the area of the Indian-Western Himalayas under snow cover has significantly reduced from 1,73,776 km² in 2008-2009 to 1,69,496 km² in 2014-2015. This reduction in snow cover of the Himalayas is directly going to impact the discharge in the snow-fed rivers of Punjab.

Mass-balance analysis, for last 40 years, of the different types of glaciers in the Himalayas i.e., clean-ice, debris-covered and lake terminating. It was concluded that net mass-balance of the Himalayan glaciers was −0.31 ± 0.13 meter water equivalent per year. Hence, it is evident that the glaciers of the Himalayas, that are the source of fresh water for various Indian rivers, are retreating. In this way, it can be concluded that before considering the distribution of rivers within the states, the matter of changes in snow fall intensity and glacier retreat should also be considered.

2.2. Requirements of Punjab

2.2.1. Demography

The requirement of the river water is directly proportional to the population of the region. Therefore, in this article the demand of river water of Punjab was compared with its population. The total population of

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**Figure 3.** Average annual seasonal rainfall variation in Punjab (2012-2017) (Source: IMD 2017)
Punjab as per 2011 census is 27,743,338 which is approximately 13.90% higher than the population in 2001. In 2011, the total population if Punjab is 2.29% of the total population of India, which was 2.37% in 2001. Therefore, it can be implied that the population of Punjab is growing exponentially owing to which the population density of Punjab was reported to be 551 citizens per km$^2$ which was 169 citizens per km$^2$ greater than the net density of India. Moreover, with the technological advancements and economic growth of the region, the urbanization of the State is taking place. As compared to 2001, the urban population was reported to increase from 33.92% to 37.48%. Therefore, it can be implied that since 2001, the need of the river has increased. The population distribution in Punjab is shown in Figure 4.

![Figure 4. District-wise population distribution in Punjab (source: Chandramouli and General 2011)](image)

2.2.2. **Groundwater level**

After surface water, groundwater is the second-most used source of fresh water. However, since the last few decades the dependence on groundwater has largely increased and subsequently, its level has reduced. Since, surface water is one of the prominent ways to recharge groundwater therefore, before deciding the distribution of river water, it is crucial to consider the dependence of irrigation on groundwater of Punjab, India. The dependence of irrigation in Punjab on the groundwater can be depicted from the annual increase in the number of tubewells installed in the state, which is shown in Figure 5.
Figure 5. Number and type of tubewells in Punjab (1980-2017) (source: PSPCL)

From Figure 5, it is evident that there are two types of tubewells installed in Punjab i.e., diesel operated and electric operated. Since, 1980 the number of electric operated tubewells has enormously increased however, trend has been negative in the case of diesel operated tubewells. Overall, the total number of tubewells has significantly increased from 6 lakhs to 14.76 lakhs i.e., net growth of 146%. In this way, it can be implied that the need of groundwater for irrigation purposes has increased significantly over-the-time. Therefore, it is crucial to sustain the sources of groundwater recharge i.e., surface water bodies.

2.2.3. Irrigation pattern

Punjab is considered as a granary of India and hence, the major occupation of its citizens is agriculture. The current scenario of agriculture in Punjab is highly dependent on the irrigation via, canals and groundwater, and therefore, demand of fresh water is generally high during both the crop seasons i.e., Kharif and Rabi. There are two major crop seasons i.e., Kharif and Rabi. The crops cultivated during these two seasons are mentioned in Table 1.

| S.No. | Season | Crops |
|-------|--------|-------|
| 1     | Kharif | Maize, cotton, rice, sugarcane, pulses (grams excluded), bajra, peas, jowar and vegetables such as gourd, onions and chillies |
| 2     | Rabi   | Gram, barley, wheat, fodder crops, potatoes, oil seeds and winter vegetables |

Since green revolution, the cropping pattern in Punjab has significantly changed and there are generally two types of crops i.e., wheat and paddy. In this way, the cultivation of other types of crops such as,
oilseeds, pulses, maize other cereals, etc., have been observed to decrease in the region. Also, with the technological expansion and new research, the high-yielding variety of wheat and paddy has been introduced that completely eliminated the multi-cropping pattern. Further, as paddy is a high water-depending crop, their cultivation demands high amount of irrigation that put extra burden on the water resources of Punjab. Increase in the irrigated area of Punjab, from 1970 to 2015, under two crops of different seasons i.e., rice and wheat.

Figure 6 shows that from 1970-1971 to 2014-2015, the cultivable-area under HYC rice and wheat crops, has increased by 2,312% and 119%, respectively. The increase in the area under HYC-rice is 2,193% higher than that of the HYC-wheat. The need of water for irrigation is also higher for rice as compared to wheat. Therefore, there is a drastic increase in the crops demanding water for irrigation and subsequently, policies also need to be updated as per the current scenario.

2.2.4. Hydroelectricity

Generation of electricity, by constructing dams on the rivers, is one of the ways of preventing floods and diverting the discharge of rivers. For the same purpose, several dams have been constructed on the rivers of Punjab such as, Bhakra Dam, Thein dam, Pandoh Dam, Pong Dam etc. Hydro-electricity is the major clean way of generating electricity in Punjab and with the increase in population the demand for electricity is also increasing. Therefore, it is crucial to predict the future demand of electricity in Punjab, in order to consider construction of further structures for generating hydro-electricity.

2.3. Associated impacts
2.3.1. Flooding

The most prominent ways of preventing the floods are either diverting the flow or constructing dams over the rivers. In earlier times, when number of canals were very less in Punjab, the number of incidents of flooding was high during monsoon season. In this regard, several dams viz., Pong Dam, Bhakra Dam,
Pandoh Dam etc., and other headworks and barrages were also constructed. The extra discharge of rivers was also reduced by constructing the canals. Currently, the major incidents of flooding are limited near the confluence of the Satluj river and Beas river i.e., near Harike headworks. Therefore, although, the flooding the major factor that may suggest toward the construction of more canals yet as Punjab is not facing substantial problems due to flooding, the further construction of canals on the basis of this factor can be eliminated.

3. Conclusions

This article illustrated that the major factors that need to be considered before further diverting the discharge of the rivers of Punjab can be categorized into three types i.e., climate change, requirements and associated problems. Climate change comprises of changes in precipitation, snow fall and glacier retreat; requirements discusses changes in demography, irrigation pattern, groundwater level and demand of hydro-electricity; associated problems mention the current and past issue of flooding in Punjab. From the discussion, it was made evident that the current situation has significantly changed from the past conditions, with respect to the various factors mentioned previously. Therefore, despite the past policies framed between the neighboring states, the current scenario of the various factors should be considered.

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