SPATIO-TEMPORAL ANALYSIS OF SOCIO-ECONOMIC IMPACTS INDUCED BY BIG DAMS: A CASE STUDY OF RANJIT SAGAR DAM

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DECLARATION

I, hereby declare that the presented work in the thesis entitled **"Spatio-Temporal Analysis of Socio-Economic Impacts of Big Dams-A Case Study of Ranjit Sagar Dam"** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Rajesh Jolly working as Associate Professor in the Department of Geography, School of Liberal and Creative Arts (Social Sciences and Languages) of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the work reported in the Ph. D. thesis entitled **"Spatio-Temporal Analysis of Socio-Economic Impacts of Big Dams-A Case Study of Ranjit Sagar Dam"** submitted in fulfilment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department Of Geography, School of Liberal and Creative Arts (Social Sciences and Languages) of Lovely Professional University, Punjab, (India), is a research work carried out by Nidhi Jasrotia, Registration No. 42000528, is Bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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Abstract

Large dams play a crucial role in water resource management, energy generation, and economic development. Large dams and their associated watersheds are critical infrastructures that support water storage, hydropower generation, irrigation, and flood control. However, their impacts—both positive and negative, extend far beyond their immediate vicinity, influencing environmental systems, socio-economic structures, and long-term regional development. A thorough understanding of the physical resources of dam watersheds, the spatial and temporal socio-economic impacts of large dams, and the risks and safety measures associated with dam failures, is essential for sustainable water management and infrastructure development.

This research aims to explore the spatial distribution of Physical resource base in Ranjit Sagar Dam Watershed region, to analyse the spatial and temporal aspect of the social and economic impacts of Ranjit Sagar Dam and to discuss how these impacts of the dam under study are perceived by different demographic groups (occupation, age and education) of Ranjit Sagar Dam Watershed region, to evaluate the potential dam failure risks to Ranjit Sagar Dam and to put forward adaptive measures to mitigate negative consequences ensuring the social well-being without compromising natural resources. A thorough review of literature at global, national, and regional levels has revealed gaps in existing research on Large Dams and particularly on Ranjit Sagar Dam. While numerous studies focus on the significance of large dams, the associated socio-economic impacts on communities, ecosystem disruptions, and changes in land use patterns, dam failure risks and mitigation strategies, a detailed analysis addressing the unique challenges and complexities of the Ranjit Sagar Dam and its watershed is still missing.

This study outlines several key objectives based on insights from the literature review and existing research gaps:

1) To find the Physical Resource Base (Topography, Geology, Soil, Riparian Vegetation, Land use Land Cover of the area under study)

2) To identify the major socio-economic impacts in upstream and downstream region of Ranjit Sagar Dam during constructional as well as operational phase.

3) To evaluate dam failure risks and dam safety measures

4) To suggest impact mitigation measures.

This study utilizes a goal-oriented approach to achieve its objectives. To address the first objective, Remote Sensing and GIS based spatial mapping technique was adopted. These results were examined in conjunction with on-site investigations to clarify the interlinked factors influencing the distribution of physical resources of the study region. For the second objective, an assessment was carried out to analyse the spatio-temporal aspect of socio-economic impacts of Ranjit Sagar Dam using both primary and secondary data sources. Primary data was collected through comprehensive fieldwork, covering 528 households across twelve villages (06 Upstream villages and 06 Downstream villages) in the study area.

The third objective evaluated the potential hydrological, geo-tectonic failure risks to the Ranjit Sagar Dam and adequacy of dam safety measures. To achieve this objective, analysis of previous dam failures, spatial mapping and review of various government reports/ research articles was done. Additionally, to assess, how the communities perceive the adequacy of dam safety measures regarding Ranjit Sagar dam, survey-based approach was adopted wherein primary data, was collected from the sampled households.

To fulfil the fourth objective, based on the results of each objective, generalisations were made and respective suggestive measures were made to avoid or mitigate the adverse socio-economic impacts, hazard risks associated with Ranjit Sagar Dam in particular. Also, various research papers and reports were analysed to recommend the mitigation measures for negative impacts of dams in general.

The entire study is structured into seven chapters. Chapter 1 presents an introduction, conceptual framework, literature review, research objectives, and methodology.

Chapter 2 explores the physical resources such as topography, drainage network, geological details, soil distribution, types of vegetation and land use land cover in Ranjit Sagar Dam watershed. The watershed consists of a combination of agricultural and forested land, impacting water quality and sediment movement into the reservoir.

Considerable erosion was observed in the upper sections of the watershed, potentially resulting in higher sediment deposition and a gradual decline in reservoir capacity.

The findings indicate that regulating land use practices, applying erosion control strategies, preserving riparian vegetation, and monitoring water quality along with conducting regular inspections of the dam area through geo-technical studies will be essential for maintaining the dam's efficiency, ensuring its safety, and promoting the long-term sustainability of the watershed. Moreover, promoting integrated watershed management, considering the interconnectedness of water resources, land use, and natural ecosystems to protect the entire watershed region safeguarding its vitality and sustainability for future generations.

The Third chapter of the study covers sections describing general information about respondents using bar graphs and pie charts, educational, occupational and income disparities between respondents of upstream and downstream region and graphical representation of survey responses using diverging bar graphs. Overall, integrating respondent information with visual data representation establishes a crucial foundation for the subsequent analysis and discussion chapters. This preliminary work paves the way for a more in-depth examination of the findings and their implications, assisting stakeholders in improving monitoring efforts and enhancing decision-making processes.

The fourth and fifth chapter examines empirically the perceptions of Upstream and Downstream respondents respectively. These chapters assess how these perceptions regarding broader themes namely 'livelihood, community and infrastructure' are influenced by occupation, age and education. Results revealed that respondent's opinions are significantly shaped by occupation and age group reflecting the need of prioritizing the views of these demographic groups while framing policies for future dams in the Ranjit Sagar Dam watershed and Ravi River basin. Also, it is generalized that socio-economic impacts of a large dam vary in space, time and demographic context.

The sixth chapter addresses the issue of potential failure risks to Ranjit Sagar Dam, wherein first section covers evaluating risks on the basis of lessons learned from previous dam failures in India which indicate that Ranjit Sagar Dam's body may be a high potential risk location in case of a failure due to overtopping. The next section evaluates potential hydrological and geo-tectonic risks to Ranjit Sagar Dam. Findings indicate that increased inflow into the reservoir during monsoon, seasonal fluctuations in water level and the initiation of Glacial Lake Outburst Flood (GLOF)-related incidents in Ranjit Sagar Dam catchment area may be the potential hydrological risks. Moreover, the presence of local faults adjacent to the Ranjit Sagar Dam and high seismicity in the region may be the impending threats to the safety of Ranjit Sagar Dam and other dams in its watershed. It implies that incorporating climatic change adaptation, the suggestions of geo-technical studies into dam related policies, stricter safety regulations, enhanced monitoring, and improved emergency preparedness can help mitigate long-term threats.

The seventh chapter discusses the policy implications of main findings and puts forward a set of comprehensive recommendations aiming to mitigate negative impacts/risks associated with Ranjit Sagar Dam in particular and other large dams in general.

This research set forth an Integrated Framework which emphasize the need for a balanced watershed level approach to study socio-economic impacts of dam construction and operation, taking into account the needs of all stakeholders in addition to the optimum utilization of physical resources present in dam's watershed and minimizing the related hydro-geotectonic risks to dam safety which may impact the socio-economic sustainability in entire watershed of a dam. Ensuring that the benefits of the dam are widely shared while addressing the concerns of impacted communities—particularly those in the upstream and downstream regions—will be key to mitigating negative effects and promoting sustainable development. The good consequences of the dam may be maximized while limiting its negative effects on infrastructure, livelihoods, and community well-being through fair compensation, inclusive engagement, and strong environmental safeguards. All the planning and effective implementation should be Time, Space and Community (Demographic Groups) specific as the impacts/risks associated with large dams are controlled by these three factors. Further, it is recommended that future research should focus on comparative analysis of impacts of dams in Ravi River basin, multidisciplinary approach to reveal intricate connections of large dam dynamics, use of remote sensing, GIS in mapping and tracking dam's socio-economic, environmental and failure impacts for Ranjit Sagar Dam watershed management and conservation planning.

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CHAPTER-1

CONCEPTUAL FRAMEWORK AND METHODOLOGY

1.1 Introduction

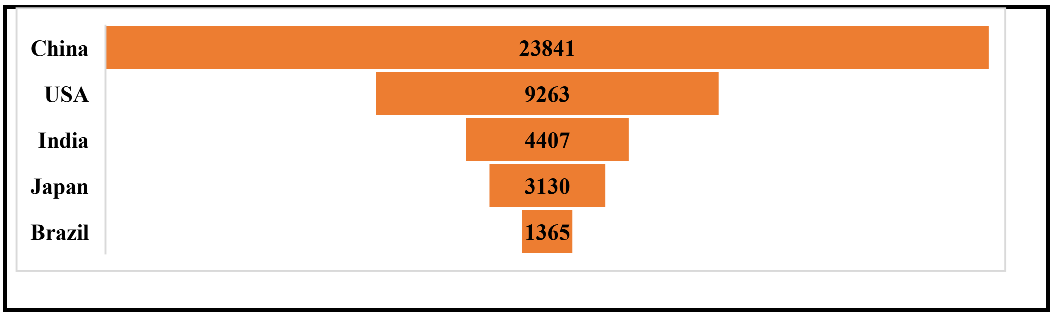
Water is a crucial resource that sustains all life on Earth. It is fundamental to the well-being of human society and plays a key role in growth, development, and maintaining the health of the global environment (International Commission on Large Dams, 2022a). As Earth surface has approximately 71% water and 29% land, so Earth is regarded as the blue planet (Byatt et al.2001). Oceans account for around 96.5 percent of all water, with the remaining fresh water coming from rivers, lakes, icecaps, glaciers, subterranean aquifers, and so on. However, the irony is that water supplies are dispersed unevenly over the landscape. These regional variations in water distribution are the reason why many people around the world still do not have adequate water for drinking, sanitation and irrigation. Floods occur in some areas, while droughts exist in others. Dams have been used to address regional variations in water availability since antiquity (Castelan, 2002). According to Schhnitter (1994), the first dam was built in Jordan around 4000 BCE, and the Sadd El-kafara dam was built in Egypt around 2600 BC. In recent times, the Spanish were the leaders in dam construction circa 1600 CE (Tullos et al. 2009). Currently, there are around 800000 dams built and in operation around the world, with 50000 being big dams (Kornijowl, 2009). According to the International Commission on Large Dams (2011), 'A dam with a height of 15 metres or greater from lowest foundation to crest or a dam between 5 metres and 15 metres impounding more than 3 million cubic metres.' Regardless of size, whether little, huge, or medium, dams are the need of the hour all over the world, where the top three most populous countries in the world China, India, and the United States are also the countries with the most dams, with China having 23,841 dams, followed by the United States (9263) and India (4407) (Fig 1.1)(World Register of Dams, 2020a).

1.1.1 Classification of Dam

A dam refers to any structure built across a river or stream to store or redirect water (ANCOLD, 2022). It encompasses additional components like spillways, outlets, water conveyance systems, hydromechanical equipment, energy dissipation devices, river management works, and other related structures that are essential to the dam, its reservoir, or surrounding areas (Central water commission,2020). The most common type of dam is the earth fill embankment dam, followed by gravity dams and rockfill embankment dams (Figure 1.2).

Figure 1.1

Dams: Top Five countries with the greatest Number of Dams



Source: World Register of Dams, 2020a

Table 1.1

Dams: Classification on Basis of Design, Size and Purpose

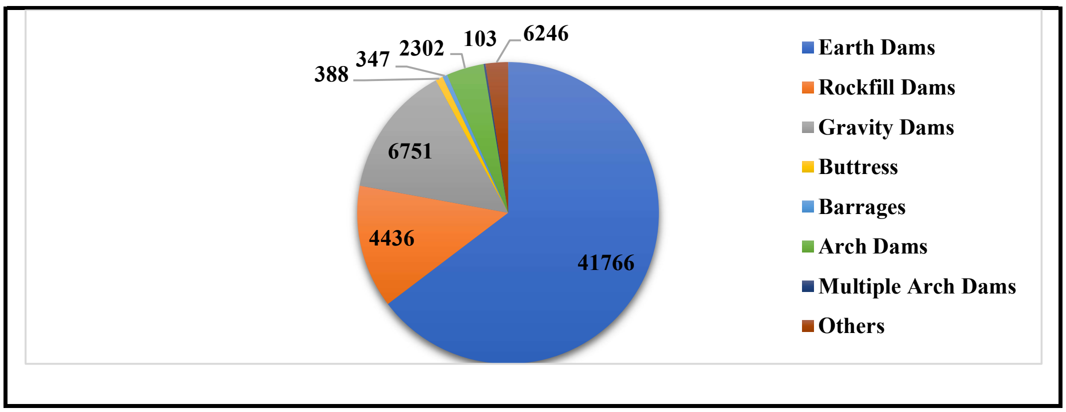
On the Basis of Material and Design	On the Basis of Size	On the Basis of Purpose
• Earth Dam • Rockfill Dams • Gravity Dams • Buttress Dam • Barrages • Arch Dam • MultipleArch Dams	• Large Dams • Small Dams	• Single Purpose Dams • Multipurpose Dams

Source: ASDSO,2024 ; US Society on Dams (USSD), 2025; World Register of Dams ,2020b

As per available data, Asia has highest percentage of large dams, accounting for 39% of the total dams. This is followed by North America which make up 32% and Europe which represents 19% of the total large dams globally (Figure 1.3). Table 1.1 Classifies Dams on the basis of size, purpose and design. Furthermore, World Commission of Dams categorises the purposes of dams in nine categories (Table 1.2). As shown in the Table 1.2, irrigation is the most common purpose of dam construction followed by hydropower production.

Figure 1.2

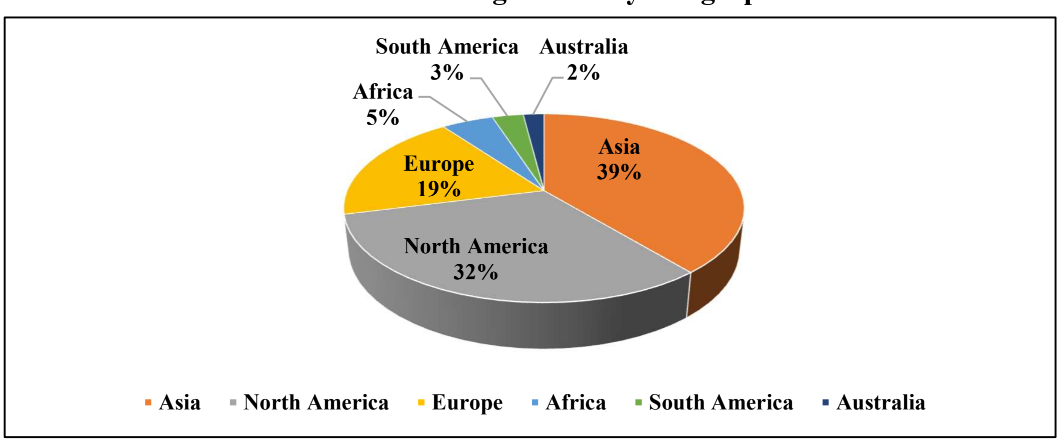
Dams: Number of Different Dam Types Worldwide



Source: -World Register of Dam , 2024

Figure 1.3

Dams: Distribution of Large Dams by Geographical Area



Source: - International Commission on Large Dams, 2022a

Table 1.2

Dams: Various Purposes of Dam's Construction

Code	Description	Dams with Sole purpose	Multiple-purpose dams
C	Flood control	2512	5195
F	Fish farming	63	1864
H	Hydropower	6154	4413
I	Irrigation	14743	6894
N	Navigation	79	601
R	Recreation	1521	3288
S	Water supply	3462	5254
T	Tailing	1877	83
X	Others	1062	1616

Source: World Register of Dams, 2024

1.1.2 Dams in India

The country is abundant in water resources, and building dams has been a long-established engineering practice (Kanjlia et al.2021). Earth dams for storage and diversion works have been built in India since pre-historic times. A few projects constructed during second and third century A.D. in South India are still providing useful service (Task force (TF5),2004). At present there are 5264 completed large dams and 437 large dams are under construction in India (NRLD, 2018). In India, the increasing demand for water and electricity is a major factor driving the construction of more dams. As groundwater levels continue to decline, the need to meet the growing population's water and food requirements will intensify, leading to greater pressure to build additional dams in the future (Sharma, 2019). The 50,000MW Hydro Electric Initiative launched in 2003 aimed to build 162 new large dams which are in various stages of development. Presently, hydropower accounts for 14% of total generation capacity in India (Damle,2021).

1.1.2.1 Dams of National Importance

According to (Central Water Commission, 2012), 'These are the dams with height of 100 meter and above or gross storage capacity of 1 billion cubic meter and above'. There are 65 completed and 11 under construction dams in India in the category of "Dams of National importance" (NRLD,2018). Fig1.4 shows the top ten dams in India with height above 100 meters.

1.1.4 Benefits of Dams

Dams are primarily built to provide the following four key benefits:

• To fulfil the growing demand for water (Eiriksdottir et al. 2017).

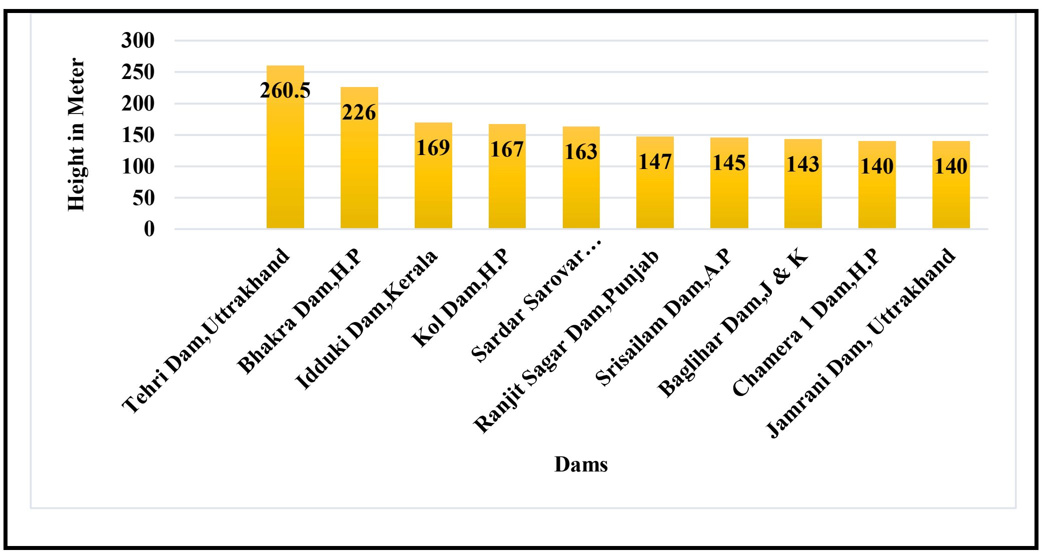
• According to Altinbilek (2002), the goal is to give electricity to growing cities and industries.

• To irrigate agricultural areas (Brown, 2009).

• According to Brown (2009), flood prevention involves diverting excess river water to drier regions.

Figure 1.4

Dams : Height of Some Large Dams in India

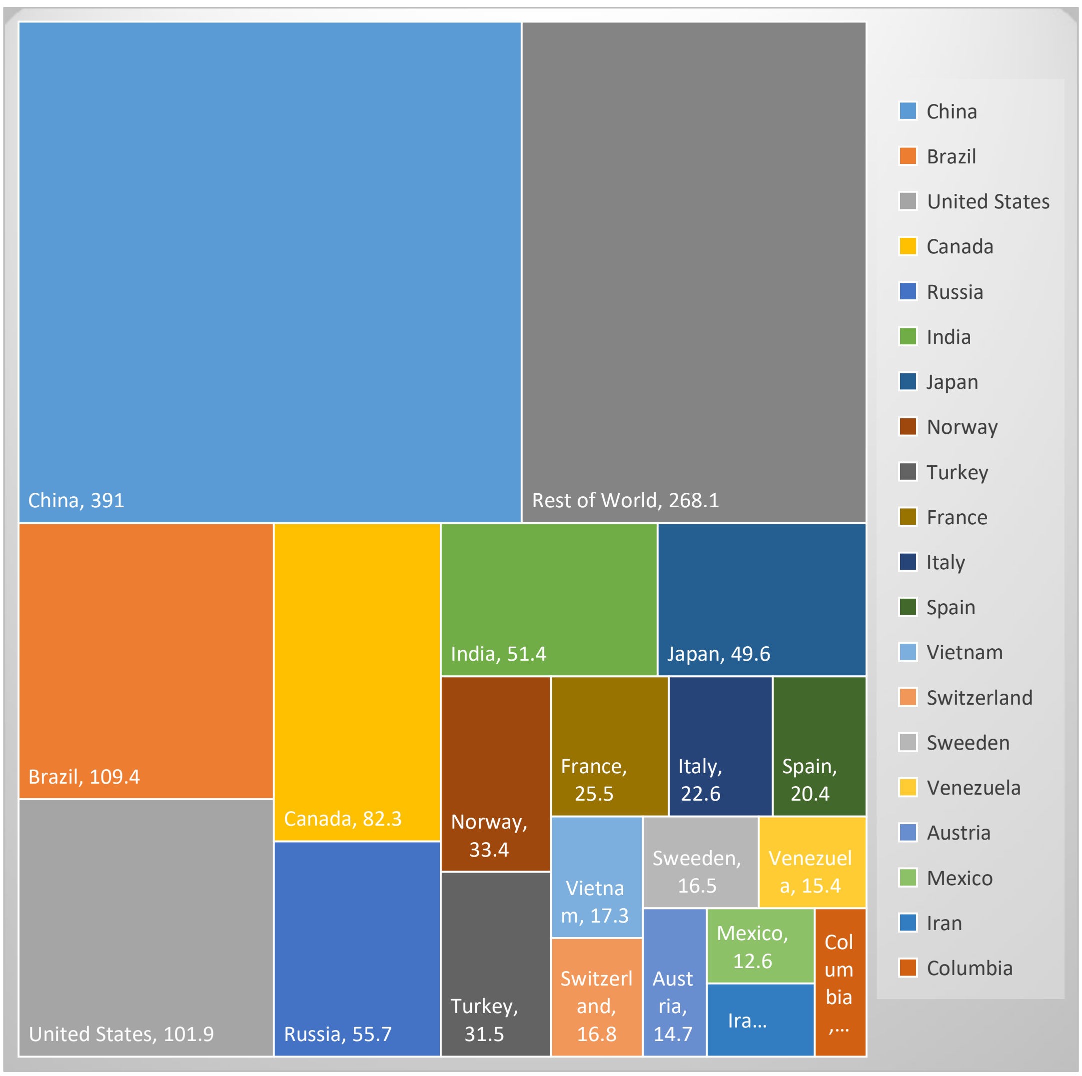


Source: - NRLD,2018

According to the World Bank (1996), without the use of rivers, the world would be vastly different, with fewer sustainable human settlements. For many people living in the world's major river basins, life would involve a recurring cycle of droughts, floods, and famine. Energy produced by hydroelectric plants worldwide accounts for roughly one-fifth of total electrical energy (Altinbilek, 2002). According to the International Renewable Energy Agency (IRENA, 2021), to help keep the global temperature increase well below 2°C, the world's current hydropower capacity must expand by approximately 60 percent by 2050, reaching a total of 2150 GW. According to Hydropower Status Report , in the year 2021, the total hydropower installed capacity reached 1360 GW, with the top six countries being China, Brazil, the United States, Canada, Russia, and India (Fig.1.5) (International Hydropower Association, 2022).

Figure 1.5

Dams: Country wise Hydropower Installed Capacity, 2021 (1360 GW)



Source: International Hydropower Association, 2022

Dams are highly beneficial as they can store large amounts of water in reservoirs, enabling them to generate electricity on demand, which other power sources like thermal and nuclear energy cannot do (Egrea & Milewski, 2002). Considered significant social investments, dams play a crucial role in the future development of both urban and rural populations, particularly in developing countries (Dixon et al., 1989). They help manage flood risks and support floodplain agriculture (Poff & Hart, 2002). The IPCC (2007) predicted that, due to increased precipitation events, areas affected by droughts and floods will grow, and the impact of these events can be mitigated by dams (Tullos et al., 2009).

According to a study by the United States Committee on Large Dams (USCOLD) in 1997, the construction of dams has undoubtedly improved living conditions for people. Dams are an effective means of managing limited water resources sustainably, meeting the growing demands for potable and industrial water, as well as addressing the increasing energy needs (Altinbilek, 2002).

Benefits of some of the major dams of the world are summarized in Table 1.3. Dams contribute much more (Figure 1.6) than the profits listed above, such as minimal carbon emissions and very low pollutants in the air (Jumani et al. 2017). Thus, hydropower has the potential to serve as a critical bridge to the urgently needed transition to sustainable energy (Goodland, 1995). Dams improve people's socioeconomic standing by offering modern infrastructure and employment opportunities (Brown et al. 2009). For example, Ghana's Bui Dam improved transportation networks, drinking water, health, and education (Mortey, 2017). Dams also give recreational and navigational opportunities, as well as economic benefits to society (Brown et al. 2009). Among the 17 Sustainable Development Goals (SDGs) established in 2015 by 193 nations, "Affordable and Clean Energy" and "Zero Hunger" focus on eradicating extreme poverty, reducing inequality, and safeguarding the planet as part of the 2030 Agenda (United Nations, 2023). Indeed, achieving these goals requires a focus on hydropower, provided the issues related to dams are thoroughly examined and addressed through effective planning and policies. It is essential to highlight the challenges associated with dams, which will be discussed in the following section.

Table 1.3

Dams: Associated Profits/Uses of Some Major Dams Worldwide

Dam (Country)	Profits/Uses
Chicoasén Dam (Mexico)	9% for water supply, 42% for agriculture, 39% for hydropower (Castelan, 2002).
Ataturk (Turkey)	Contributes about 3.8 billion US $/year to its economy by irrigating 882000 ha land which is about 56% of the total irrigated land and generating 8900 GWh/year energy (Altinbilek, 2002).
Grande Dixence Dam (Switzerland)	Hydropower contributes 59.6% of electricity (Kellner, 2019).
Sardar Sarovar (India)	It has two power houses of 1200 MW & 250 MW each. Irrigates 18.45 lac ha land in Gujarat, provides drinking water to 173 Urban centers and 9490 villages, flood protection to 4 lac population of Gujarat, (Sardar Sarovar Narmada Nigam Ltd., 2021).
Three Gorges (China)	It protects about 15 million residents and 3.7 million acres in the Lower Yangtze floodplain (Earth observatory, 2007).
Tucurui (Brazil)	It Supplies electricity to 13 million people (La Rovere and Mendes, 2000)

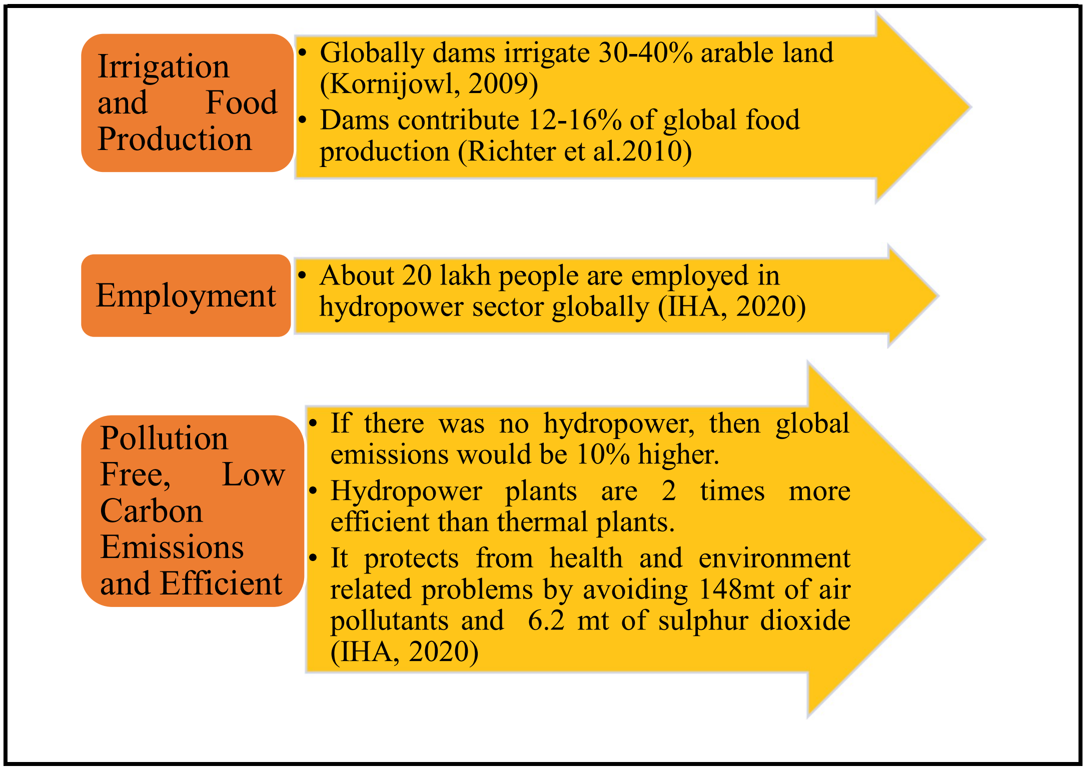
Source: Compiled by Author from Various Sources

1.1.5 Adverse Impacts Associated with Dams

Dixon et al. (1989) discovered that dams provide immediate advantages, but there are several linked environmental and social consequences, many of which are likely to constitute costs. Globally, the principal challenges arising from dam construction can be classified as socioeconomic implications (Rao 1989, Pinho et al. 2007, Sharma and Thakur 2017) and environmental impacts (Richter et al. 2010, Pinho et al. 2007). The World Commission on Dams (2000) claims that "shortfalls in technical, financial and economic performance have occurred and are compounded by significant social and environmental impacts of dams, the costs of which are often disproportionately borne by poor, indigenous people and other vulnerable groups".

Figure 1.6

Dams: Contribution in Global Agriculture, Employment and Pollution Mitigation



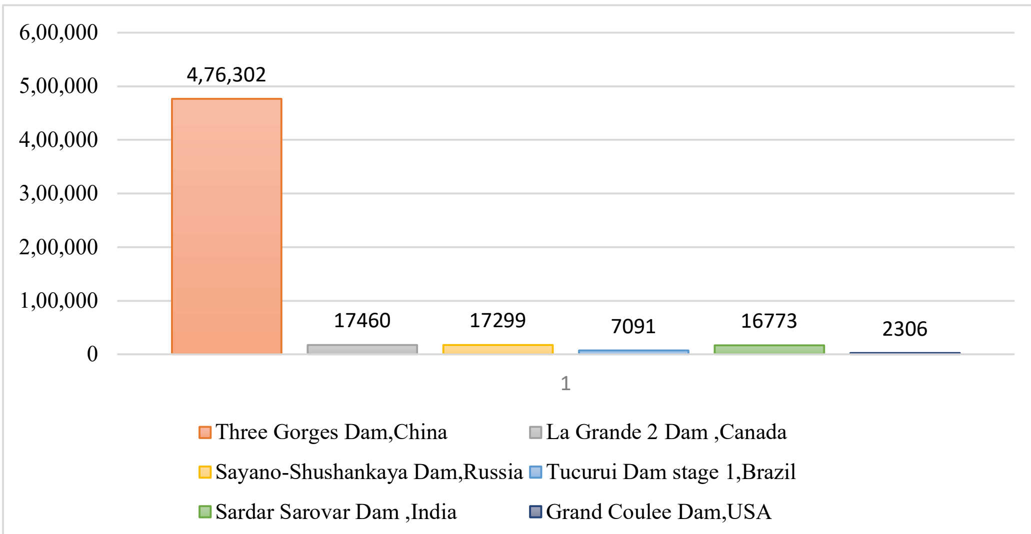
Source: Compiled by Author from different sources

These negative repercussions frequently lead to excessive cost/schedule overruns for dams (Figure 1.7). The impoundment and presence of reservoirs in dam construction are the primary sources of dams' negative socioeconomic and environmental repercussions. Furthermore, global climate change and rising electricity demand exacerbate the detrimental impact of dams (Tullos et al. 2009). The intensity and scale of socioeconomic repercussions is huge in time and location, as indicated below. Involuntary displacement and resettlement have negative socio-economic repercussions (Mcnally et al. 2008, Gutman, 1994) and can disrupt social networks (Brown et al. 2009). Between 1950 and 1990, dam development displaced more than 10 million people in China alone. Similarly, in Poland, nearly 300 dwellings were flooded in the village of Maniowy while the Czorsztyn Reservoir was being filled

(Kornijowl, 2009). Gorshkov et al. (2013) highlighted the challenges associated with Russian ponds and reservoirs.

Figure 1.7

Dams: Cost Overruns (in million US$)



Source: Shaktawat & Vadhera 2020

Displaced populations experience significant negative impacts on their livelihoods, both directly and indirectly (Aung et al., 2021). In addition, locals are often deceived under the guise of employment opportunities and electrification projects (Jumani et al., 2017). Forests and agricultural lands are submerged (McNally et al., 2008), leading to food insecurity (Richter et al., 2010), heightened water conflicts (Rao, 1989), and shifts in resource allocation and usage patterns (Gutman, 1994).

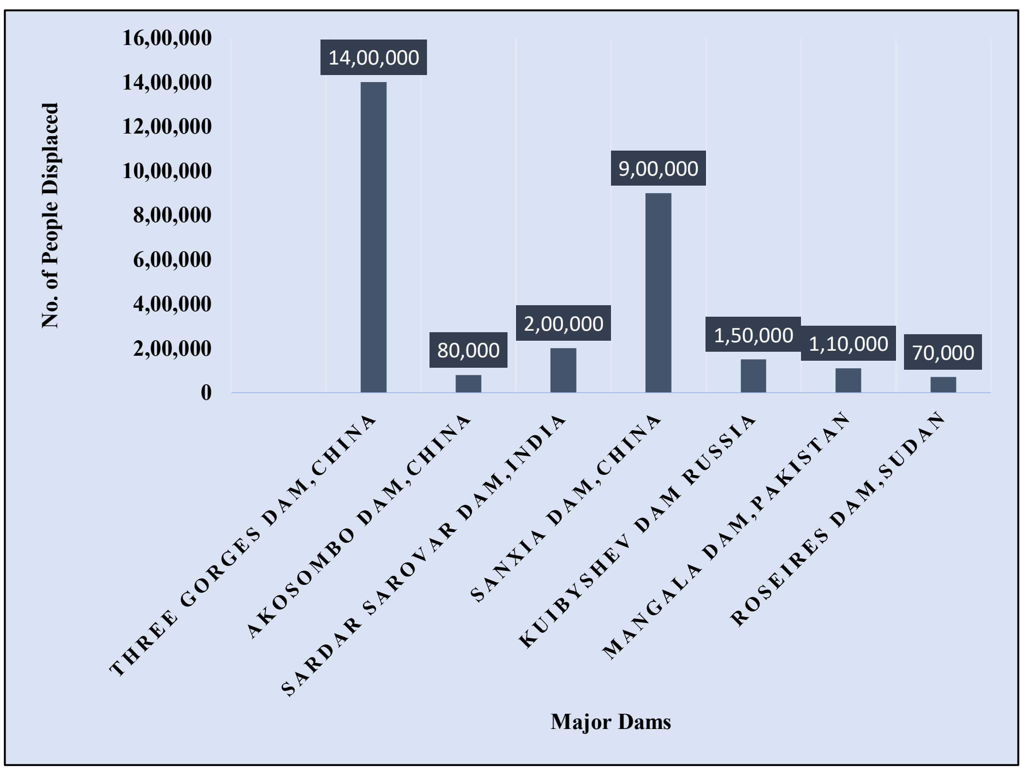
Additionally, migration to host areas due to displacement increases population density and intensifies competition for resource access (Tullos et al., 2009), thereby altering the land-to-population ratio. Sikka (2020) examined the extensive displacement caused by the Sardar Sarovar Dam in India. Chandy et al. (2012) discovered that the construction of dams in the Sikkim state of India led to changes in land use and occupations, which could negatively affect local livelihoods.

The World Commission on Dams, in its influential report, highlighted that dams are spatially impactful, locally disruptive, and tend to have long-lasting, often irreversible effects (Tullos et al., 2009). Globally, around 1,249 large dams have been built within protected areas, which negatively impact the health of these areas. As a result, dam construction in or near protected areas should be avoided (Thieme et al., 2020). The magnitude of displaced people through some of the largest dams as illustrated by World Register of Dams (2020d) shown in Figure 1.8. Table 1.4 summarizes the adverse impacts of dams.

Although large water projects induce negative impact chain in physical and social environment, yet, numerous studies point towards considering dams construction and their integration in model-based impact analysis of climate change, as reservoirs can prevent the future population exposure to floods (Boulange et al. 2021).

Figure 1.8

Dams: Major Dam Construction and Displaced persons



Source: Shaktawat & Vadhera 2020; World Register of Dams, 2020d.

Table 1.4

Dams: Adverse Impacts of some major dams in the world

Studies on Dams	Adverse Impacts
Involuntary Displacement (World Commission of Dams, 2000)	Globally, about 40-80 million people have been displaced by construction of big dams
Impacts on People Living Downstream (Richter et al. 2010)	Worldwide, 472 million rivers dependent people living downstream face impacts of dams
Catastrophical Dam Failures (McCully, 2001)	Between 1860 and 1995, 46 large dams failed, out of which 8 resulted in death of 1000 people
Health Problems (Fung et al.2019; Altinbilek, 2002)	Psychological changes and depression among displaced and water borne diseases like Malaria, Leishmaniasis and schistosomiasis
Change in River Ecosystem (World Commission of Dams, 2000)	About 60% of world`s rivers have been affected by dams and diversions
Harm to Wildlife (Gracey & Verones, 2016)	During the inundation of Tucurui reservoir in Brazil, about 300000 animals suffered post rescue mortality due to changed habitat
Methane Emissions (Kornijowl, 2009)	According to an estimate,4% of the total warming impact of human activity is due to emission of methane by reservoirs
Seismic Activity (Kornijowl, 2009)	The Vaiont dam in Italian Alps caused seismic land sliding in 1963, killing over 2500 people
Damage to Fisheries (Moran et al. 2018)	At Belo Monte Dam, 16.2 tons of fishes died in 2016

Source: Compiled by Author from different sources

In developing countries, hydropower reservoirs are often seen as unavoidable due to the lack of better alternatives to meet the growing demands for water, electricity, and the needs of rapidly urbanizing populations. These countries also face the challenge of addressing climate change by reducing carbon emissions (Biswas, 2012). Table 1.5 summarizes why dams are necessary?

Table 1.5

Summary of facts: Why are dams necessary?

Facts regarding Need of Dams	**Numbers**
Number of hungry people in the world	828 million people sleep hungry every night globally (World Food Program, 2022)
Number of people without access to drinking Water	1.5 billion people globally (IRENA 2021)
Number of people without access to clean Cooking	2.6 billion people globally (IRENA 2021)
Number of people without electricity	759 million people globally (IRENA 2021)
Number of people dying of hunger	25000 /day (United Nations 2022)
Hydropower	2.3 trillion kilowatt hours of electricity each year (World Register of dams 2020c)
Aggregate storage capacity	7714 km3 (World Register of Dams 2020b)

Source: Compiled by Author

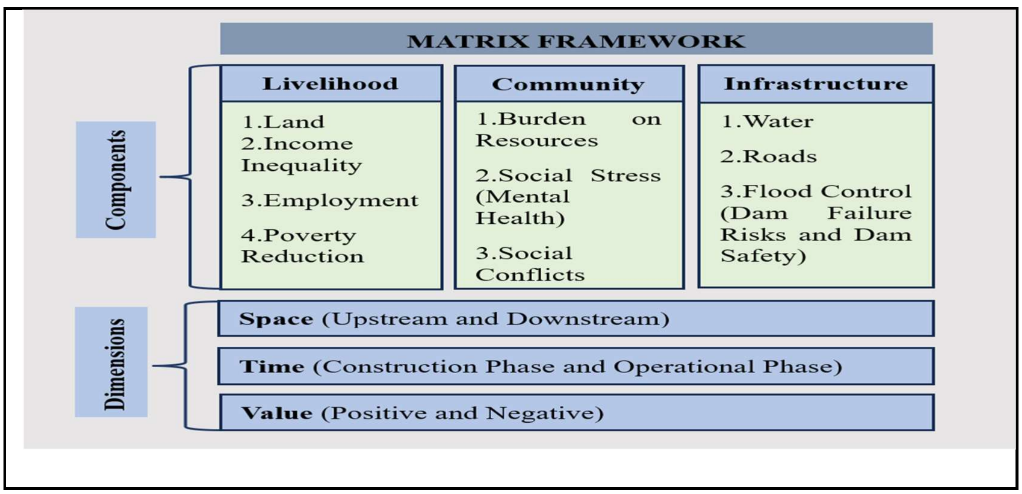
If efficient water management and effective policy implementation is done, dams represent significant alternative for socioeconomic development as they can play important role for water, food, energy at global as well as regional level along with climatic securities (Tortajada, 2015). Similarly, Goodland, 2010 accentuated that low impact dams coupled with proper irrigation and food production schemes are required to be promoted. Moreover, Beck et al. 2012 concluded that environmental and socio-economic degradation by dams depends on the time factor i.e., at which stage of development a particular region is during the dam construction and suggested the role of affected people towards sustainable development of dams. One such step is to consider all the spatial impacts of dam's construction in totality because the socio-economic impacts of large dams are so complex and intermingled that it is imperative to study these impacts involving diverse perceptions, as aptly revealed by Kirchher & Charles 2016 that spatial impacts of dams are not only confined to displaced and resettler communities but go beyond the resettlement and by study only one aspect of large dam's impacts, it is not pertinent to make a decision about the dam's overall performance and its role in regional development. Thus, analyzing different perspectives and their comparison is essential to understand holistically the impacts of a large dam project in a region where it is constructed. Thus, for the present study, Ranjit Sagar dam (Punjab), India has been selected for analyzing how its socio-economic impacts are distributed across space and time and how these impacts are controlled and modified by distribution of physical resources in the dam's watershed, associated dam failure risks and dam safety measures. This study approaches towards the role of different stakeholder's views in making dams an integral part of sustainable development. It tries to find out the interplay and dynamics of numerous factors which interact and alter the socio-economic impacts associated with large dams and suggest ways towards targeted policies.

1.2 Conceptual Framework

We adopted Matrix framework (Kirchherer & Charles, 2016) for following reasons to comparatively analyse socio-economic impacts of Ranjit Sagar Dam in space and time context. First, the framework provides a distinct and single way to analyse social impacts of dams exclusively. Second, it is relevant to our study, where the upstream and downstream region have been chosen as space dimension whereas construction phase and operational phase of dam has been selected as time dimension keeping in view the different components as explained in the framework (Figure 1.9). Our adapted framework applies the original framework's three main 'components' to our research, first discussing, land, employment, income inequality, poverty reduction under broader theme Livelihood, the second component comprises Burden on resources, social stress, and conflict under the broad theme Community and third component discusses water provision, road transport, flood control which includes dam failure risks and dam safety under the main theme Infrastructure. Moreover, the most beneficial aspect to adopt this framework is that it allows us to find the interconnection between different components also as described in later sections of this study.

Figure 1.9

Dams and Socio-Economic Impact Analysis: Framework



Source: Author's Work as reproduced from Kirchherr and Charles, 2016

1.3 Review of Literature

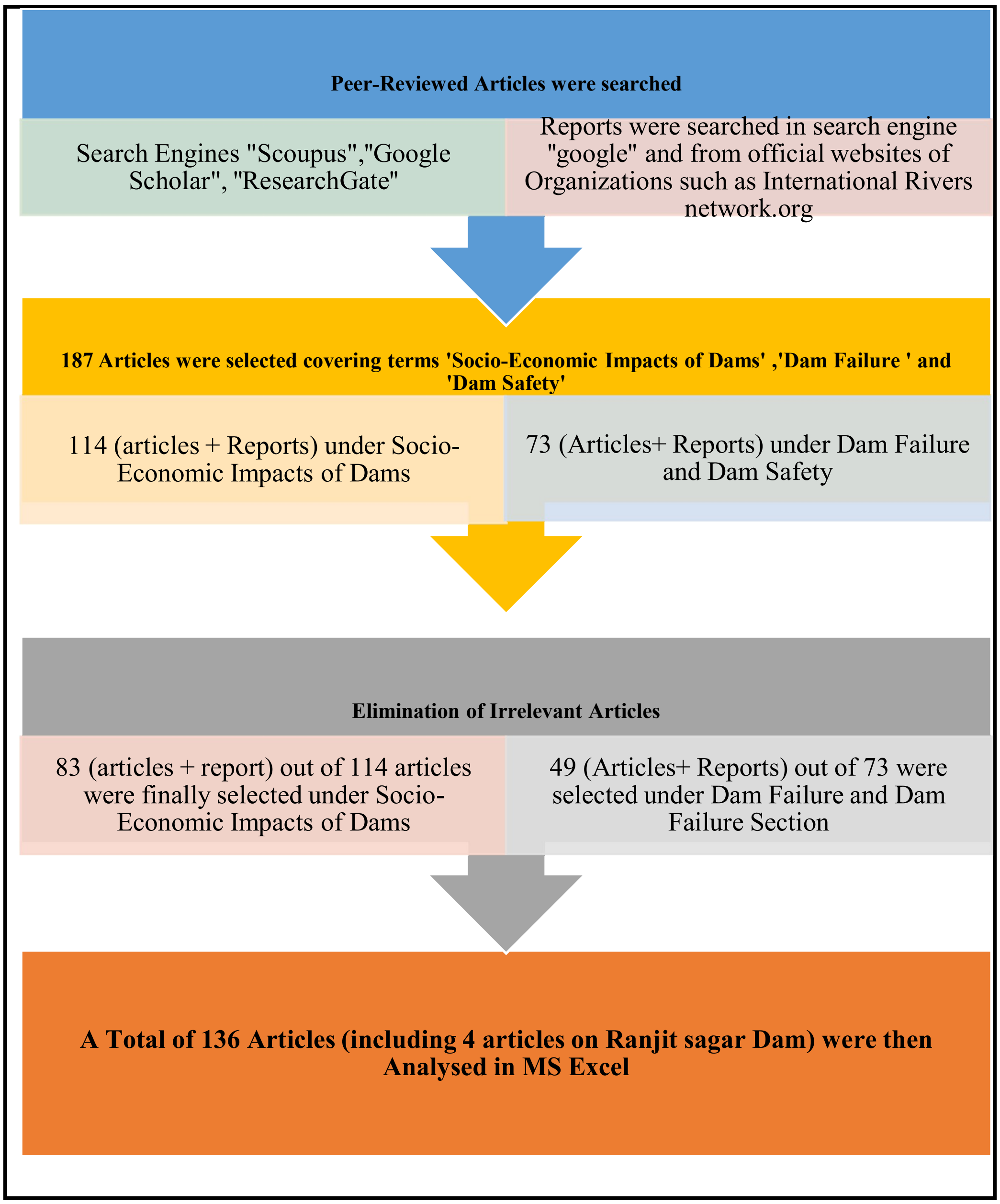
The literature review was performed on a set of peer-reviewed papers published in scientific journals between 2001 and 2024 and referenced in Scopus. It was assumed that the sample would be representative of the scientific community publishing on the research topic. The literature review exercise has been structured according to the following steps (Figure 1.10):

1) Selection of articles: Search of articles referenced by the Scopus database, reports published by organizations and other peer-reviewed articles published in journals was done from (March 2021-May 2024) and those covering the

'socio- economic impacts' and 'dam failure', dam Safety and 'dams' or 'reservoirs, 'Ranjit Sagar dam'(Figure 1.11), were included.

Figure 1.10

Review: Flow Chart of methodology used to select Articles and Reports



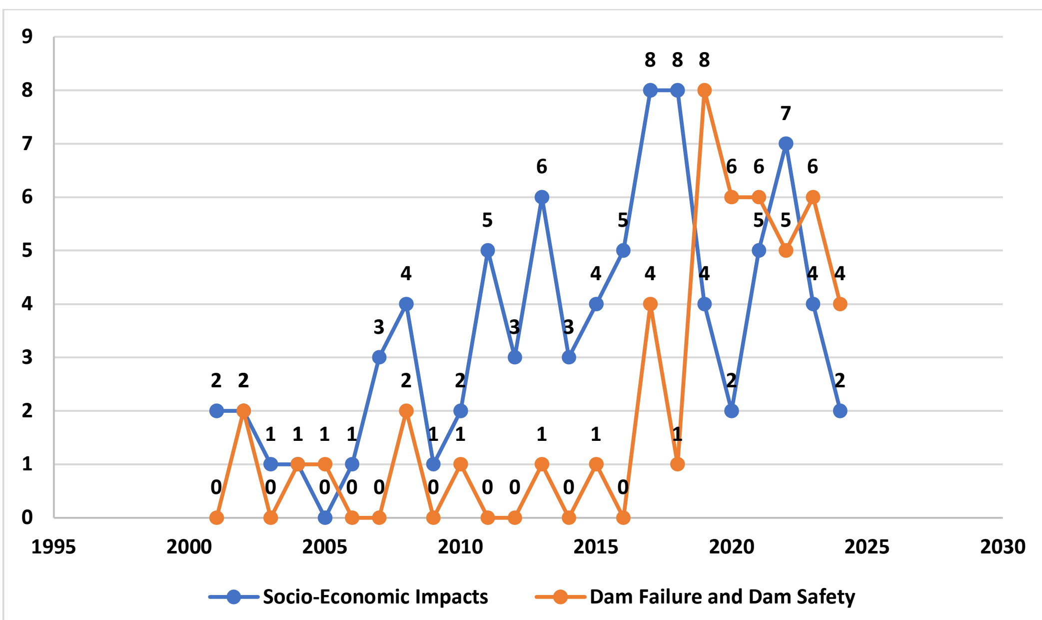
The terms were searched in the title, abstract and content fields of the articles. Under this step, 187 articles were identified. Out of 187 papers, 114 were related to socio-economic impacts of dams and rest were related to Dam Failure and Dam Safety.

2) Under this section, ‘Conclusion’, ‘Recommendations’ and ‘Adaptive measures’ of the articles were searched and irrelevant articles were removed. Under this section 83 article were selected for analysis under socio-economic impacts of dams and 49 articles were selected under Dam Failure and Dam Safety section and 4 articles related to Ranjit Sagar Dam were selected.

3) The entire content of the articles was then analysed in MS Excel.

Figure 1.11

Review: Year wise Number of Publications (2000-2024)



Source: Compiled by Author

1.3.1 Studies on Socio-Economic Impacts of Dams

Moran et al.2018 considers the need of incorporating climate change whether to build a dam or not. To address the social concerns of people living in the areas of where dams are built authors suggested that non-monetary compensations can serve as an important innovation needed for future hydro energy projects globally. All EIAs and SIAs should be carried by firms who serves the interest of locals. According to them there is need to identify the most vulnerable groups of the affected communities so that these vulnerable groups get priority during compensation process.

Abdullah and Rahman,2021 conducted the study to analyse the social impacts as perceived by host as well as affected communities including upstream, downstream and displaced residents. It was found that the Merowe dam has positive as well as negative impacts on communities studied with downstream people has strong perceptions for positive impacts as compared to upstream and relocated residents. Authors recommended for Alternative livelihood opportunities to locals affected due to project as well as emotional support to displaced and long-term monitoring of resettlement process for locals affected by the project.

Owusu et al.2017 examined the social impacts on downstream resettled communities based on distance decay concept and Matrix Framework and they found that Bui dam has improved social infrastructure but there is resource (land and Water use) based conflict that has adversely affected the farming and fishing as livelihood for community. Thus, Alternative livelihood programme as a social safeguard to downstream non resettled communities is recommended.

Shah & Kumar,2008 analysed the data of 13,631 large dams globally and found that height of dam has no relation with volume of water stored and area of land submergence. Thus, the authors suggested that for assessing the social and environmental impacts of dams a combination of criteria such as height, storage volume and area of submergence should be considered. They further pointed out that to increase the accountability on part of dam developers' costs of negative effects of projects should be built in actual cost of projects to compensate adversely impacted communities.

Mayer et al. 2022 recommended non-monetary compensation such as training for resettlers to improve livelihood for both upstream as well as downstream communities and active participation of locals should be focussed for restorative justice. Moreover, authors also suggested that SIAs should be carried by firms serving the needs of affected people. Arantes et al.2023 found that both upstream and downstream communities in Maderia River were impacted due to losses of fisheries production and profits and highlighted the need for Livelihood Adaptation strategies and capacity building of locals involving the better trade-offs are essential for fair and transparent mitigation and compensation process.

Owusu et al. 2016 examined the socio-economic impacts due to Kpong dam (Ghana) on livelihood of downstream communities (Resettled and non-Resettled). The study put forward the point that irrigation facilities can be useful only when constraints such as lack of agricultural inputs are addressed. According to the authors Compensation schemes should also include non-resettled communities upstream as well as downstream. There is need of effective involvement and participation of locals in all the stages of decision-making for dam projects.

Asamoah et al. 2020 applied a unified approach of remotely sensed data with socio-economic data for analysing the spatial socio-economic impacts of Bui Dam on downstream communities. It was concluded that Bui dam led to both positive and negative social impacts, but negative impacts are far more common and exceeds the benefits of the dam. The authors gave the idea of considering Diversified livelihood opportunities for people living downstream and their participation in decision-making process.

Magsi et al. 2022 identified that unfair land acquisition, improper displacement and mismanaged compensation are the cause of adversities due to (*Chotiari* and *Diamer Bhasha* Dams) from Pakistan on locals and highlights the need for enhancing the capacity and capability of local population and involvement of all stakeholders and diffusion of information among them. Sabir et al.2017 examined the conflicts emerging due to Diamer Bhasha Dam in Pakistan. It was found that unfair land acquisition, improper displacement, inadequate compensation, resettlement and future livelihoods are the major causes of rising conflicts. Thus, for successful dam project, resolving conflicts is the key step that can be achieved if due consideration is given to Improved capacity building programmes for locals and enhancing their skills, their involvement for increasing their capabilities to decide and launch common actions.

Mahato & Ogunlana, 2011 presented this study to develop a model for or a comprehensive and integrated approach to managing interface conflict from the early stages of a dam construction project involving project affected people. The study reveals that ineffective Environmental Impact Assessment, lack of public participation and mutual consultation, on time-to-time basis and accurate information from the early stages of projects is the main cause of interface conflicts at the construction stage of projects. It is recommended that Monitoring of resettlement programme to develop mutual trust among dam developers and affected communities, active public participation to create a sense of belongingness and project acceptance are essential to lessen the conflicts in dam projects.

Rana et al.2007 discussed the implications of socio-economic impacts of dam projects in Uttarakhand Himalayas and suggested that even the projects involving little submergence and less loss to fragile ecosystem can proved to be a failure if due care is not taken. Further, the authors illustrate how with the local’s participation and suggestions, the conflict was resolved to construct 22.5 MW Bhilangana hydro project but not at the cost of their traditional domestic need of water thus emphasizing that locals should never be alienated in developmental planning.

Nüsser,2003 discussed the adverse ecological and social consequences of large dam projects and with The Lesotho Highlands Water Project (LHWP) used to illustrate the issues related to these water structures. The study figured out that insufficient compensation and eventual lack of economic opportunities for displaced community is the major socio-economic problem associated with large dam building. Thus, the study call attention to provide adequate information in transparent manner to affected and general public and their active participation in intense debate for dam-planning is crucial step to consider.

Baird et al. 2021 focussed on studying the downstream impacts of dams and how the participation of indigenous and locals can be used to mitigate these impacts. The authors studied dams from three region namely the Peace–Athabasca in Canada, the Mekong in mainland Southeast Asia, and the Amazon in Brazil to demonstrate how the downstream impacts are often ignored due to number of factors such as long distance of these communities from dams, administrative boundaries. Further it is asserted that applying indigenous and local knowledge consistently and in appropriate manner can reduce, avoid and plays an important role to compensate appropriately for downstream impacts of dams.

Kyaw, 2018 examined the possible effects of dams on downstream communities as a case study of proposed Hat Gyi dam (Myanmar). It is concluded that women face effects more severely due to struggles in daily life and existing gender discrimination in the society. The cause of these socio-economic impacts is the lack of coordination between local governance, construction companies and local people. The research puts emphasis on Using media and communication to aware people about enhancing knowledge, skills and to support them to discuss common issues and working together on influencing public policies regarding dam construction and their impacts downstream

Jima et al.2022 studied the impact of two hydropower dam reservoirs (in Ethopia) on the adjacent household food insecurity. The researchers found that albeit two dams were built to increase food security but the results showed that there was no positive impact of dams regarding food security thus the authors recommended to effectively design the hydropower reservoirs so that impacts on locals and adjacent communities can be reduced. Sciliano et al.2015 analysed the data collected from villages located downstream from the Kamchay Dam and found that Costs and Benefits of Kamachy Project are unequally distributed between urban and rural people as the priorities of locals and those at national level are different. The study revealed that to enhance the implementation of social mitigation and development measures; to cope with unequal spatial distribution of costs and benefits among urban and rural areas and to minimise the complex and diverse impacts of large dams, active participation of different affected communities is must.

Pirog et al.2019 surveyed upstream and downstream dam affected communities and analysed that emotional and economic benefits affect the people’s perception of the Mucharski Reservoir in Poland. Respecting locals’ interest and opinions while drafting development plans and new opportunities significantly affect the social perception of the dam project by local population is highly recommended. Biswas, 2011 asserted that there should be no debate on whether small dams or big dams should be built because a mix of both dams is need of the hour depending on the conditions of specific area.

Moreover, people of the particular area should be given the right to decide whether dam should be built or not and therefore needs of local areas must be focussed while selecting solutions for properly planned and designed dams.

Chen et al.2016 addressed the relevancy of constructing more dams in today's world by analysing data on key global socio-economic impacts and role of large dams in sustaining societies. The research indicates that dam construction should be considered in order to meet the food, water and energy demand of rising population mainly in developing and least developed countries and emphasises the need of better construction, operation of dams to lessen the adverse impacts. Furthermore, the authors pointed out that to improve infrastructure development and to address externalities of dam projects, engaging affected individuals in political process is very important.

Schulz et al.2019 studied the public views regarding dam construction in Brazil's Upper Paraguay River Basin. The authors found that majority of the respondents preferred dam building on some rivers only and keeping others free flowing for ecology and fisheries connection. Furthermore, it was suggested that the overall magnitude of conflicts regarding dam projects can be reduced by enhancing political legitimacy if a strategy based on values of local citizens is implemented. Lahiri-Dutt, 2012 illustrated the impacts of Damodar Valley Corporation particularly on women asserting that large water control projects have gendered impacts on agricultural society. The study underscored that since large water projects have significant gendered impacts, local women must be focused while implementing resettlement plan.

Diduck et al. 2013 examined two hydro projects in Chamoli District of Uttrakhand and investigated how different stakeholders perceived the impacts of these projects and their participation in mitigation of these impacts. It was found that various groups viewed impacts differently. The study highlights that public participation can improve decision making by promoting equity and creating opportunities for sustainability learning. Choudhary, 2013 remarked that Legal mandate of public involvement in the overall project decision making is limited and it is seen merely as a tool to have consent of people with minimal challenges. Conflicts can be reduced by enhancing the scope of public hearing.

According to Katoch et al. 2016 all planning and policies regarding large dam projects must be directed towards avoiding or minimizing the impacts on locals and the interests of local people must be listened to and taken care of during planning. Tullos et al.2010 asserted that there are many challenges remain in analysing diverse perspectives on socio-economic impacts of dams. The study used IDAM tool for assessing the magnitude and salience of dam's impacts. It was found that stakeholders views are influenced by quality of information provided. Researchers suggested that decision support tools integrating magnitudes and importance of impacts is urgently required. In addition, they emphasized that that no matter which tool is used to assess impacts of dams; perspectives of different stakeholders must be considered in decision making.

Obour et al.2015 studied the impacts of Bui hydro project (Ghana) on the livelihood of locals. The study found that while the Bui Dam performed better than other dams in terms of resettlement and compensation, yet there are some limitations in the process. It is suggested that there is need to improve the agricultural practices for enhancing food securities and economic status of locals. Also, to avoid disruption of traditional economic and cultural activities of locals, it is imperative that local leaders must be consulted during planning and decision-making process.

Dopico et al.2022 explored social attitudes of respondents belonging to two regions with contrasting climate and water security. It was found that recognition of services provided by a dam depends on the availability of water in the region. Social awareness of both impacts and services provided by dams and reservoirs may depend on local climate and water security. Different stakeholders have different level of dam acceptance which emphasizes that locals must be involved in the decision making for water management.

Nayak, 2013 examined the case of Hira Kund Dam and illustrated the issues of social justice and equality. The risk of impoverishment to the Hirakund Dam oustees could have been mitigated if there were better negotiations and consultations with them. The oustees who not only lost their income and wealth but liberty and opportunities could have been relocated in areas of irrigation facilities but government did not consider consultation with them.

Negi & Punetha, 2017 analysed people's perceptions on impacts of hydro power projects in Bhagirathi River Valley. The study concluded that polluted river water, decreased agriculture are some of the major negative impacts whereas road infrastructure, increase in standard of living are some of the major positive impacts perceived by PAPs i.e. Project Affected People. The study underscores the need of making Hydropower more sustainable, multi-disciplinary scientific studies involving project affected people need to be carried out and also adopting low carbon electric power technologies and promotion of decentralized energy strategies using locally available renewable resources is necessary.

Ansar et al.2014 investigated the debatable question 'Should Dams be built' using an outside reference system-a model based on data of dams to predict schedule and costs overrun in dam construction. The authors asserted that in the long run dam building is less likely to produce positive impacts due to long time it takes for its construction and costs involved in building these water structures. So, it is advisable for policymakers in developing countries to use agile energy alternatives that can be built in short time period so that the risks associated with large dams such as delays and cost overruns can be managed along with other alternatives.

International Rivers, 2011 put forward that for strengthening water and energy access to poor, clean energy technologies and water efficient methods are required as these will also be helpful to build up our resilience to climate change while avoiding the major socio-ecological problems that come with big dams. Negi, 2017 studied the impacts of Hydro projects in Uttarakhand state (Bhagirathi) river valley where numerous positive as well as negative social impacts were evaluated. It was concluded that to increase the energy supply in the Uttarakhand state, there is pressing need to adopt low carbon energy technologies as well as utilizing the locally available renewable resources. Also, multidisciplinary participative studies should be carried out to make Hydropower in the region eco-friendly and sustainable.

Schmitt& Rosa, 2024 emphasized the role of dams in mitigating climate change and fulfilling the basic needs and energy demands in the present century. Using in-depth review of datasets applying machine-learning it was found that South Asia region has the greatest challenge to deal with the ever-growing need of water storage and energy.

The study highlighted the need to find nature-based water storage solutions and other forms of renewable energies so that societal demands can be met without being suffered from negative externalities of big water structures.

Gupta ,2021 carried the study to evaluate the long-term consequences of some selected Indian hydro projects. It is found that there are very limited number of studies have been carried out to analyse the long- term social impacts after the dam's construction. According to the study, a major discontent against the mega dam projects is the inadequate compensation and improper rehabilitation of displaced. Owusu et al.2018 examined the consequences of Bui Dam on the livelihoods of downstream communities using a modified Political Ecology Framework. Results indicate that downstream communities are not compensated in any form and traditional livelihood practices like farming and fishing have been disrupted leading to decreased incomes. It is pointed out that Job training and management skills should be provided to non-resettled downstream communities to improve their livelihood.

Manatunge & Takesada, 2013 asserted that diversified agricultural activities and land-based compensation should always be supplemented by proper irrigation facilities. Sivongxay et al.2017 used Sustainable Livelihood Framework to examine the social impacts of dam's construction and operation on downstream communities of four hydro projects in central Laos. The study found that positive impacts of the case study dams outweighed the adverse impact on riverine fisheries and satisfaction level among downstream communities was high where livelihood improvement program was implemented and educational and healthcare facilities were provided by the dam operators.

De Faria et al.2017 used econometric method to evaluate county level social impact indicators of 56 Brazilian hydro projects built between 1991 to 2010. It was found that the social indicators like income level, education, access to piped water in counties with hydro projects did not differ statistically from social indicators of regions without these projects. The positive socio-economic impacts of large hydro projects were short lived and there is need to turn short term economic growth into long term development. Ayeni & Ojifo, 2018 found that majority of the selected communities have not livelihood from dam and irrigation scheme is grossly under-utilized, there is need to provide employment to locals and displaced must be properly compensated.

Duflo & Pande, 2007 studied the productivity and distributional effects of Indian dams constructed for irrigational purposes. Results indicated that agricultural production increases and rural poverty decrease in downstream districts of dams as compared to the districts where dams are built. One of the main reasons associated with unequal distribution of costs and benefits of large dam construction in India is the institutional quality. So, there should not be institutional favouritism for economically and politically advantaged people.

Fan et al. 2022 examined the multiple impacts of hydropower dams in the nearby areas. It was analysed that the Global gross Domestic Product and Global Population fall by one-third in nearby areas of world's 7155 hydropower dams. In Global South, recently built dams are associated with reduced local economy and greenness within 50 Km of dam sites. So, policy interventions are recommended to address these impacts on population residing with in the vicinity of dam sites. Biswas & Tortajada, 2018 emphasized that for enhancing societal welfare, Dam construction must be better planned and operated than ever before in history so that food, energy, and water securities can be ensured.

Richter et al. 2010 highlighted that there is an urgent need for integrating all stakeholders, assessment options, dam siting, dam designs, monitoring and adaptive management so that social inequities between dam disadvantaged people and dam beneficiaries. Biswas & Tortajada, 2001 asserted that in view of developing countries dam construction is very necessary compared to developed nations as both have different techno-environmental conditions. Thus, for human welfare, especially in developing world eradicating poverty and preserving environment, it is essential to improve the overall effectiveness of dams.

Zarfl et al. 2014 pointed out that numerous dams are planned or under construction globally to fulfil the electricity gap, yet these dams will not be sufficient to eradicate completely the related issues and conflicts. Thus, in wake of current boom of global dam construction, it is urgently required that social' economic and ecological issues related to it are assessed and attenuated. For doing that it is suggested that a comprehensive mapping of current and planned hydropower can be used to apply a systematic management approach to assess the cumulated impacts of multiple dams with in a river basin.

Narayan, 2001 suggested that lessons should be learned from the shortcomings and mistakes in the water resources development projects with dams in the past to make the future projects better as a realistic solution in India. Castelan, 2002 investigated the role of dams in development of Mexico. The study highlighted that many of the negative impacts of large dams in Mexico are due to improper management, inefficient planning and inadequate expertise. Thus, using more equitable and modern water management practices can reduce the negative impacts.

Siegmund Schultze, 2018 examined the usage of INNOVATE project for sustainable use of water resources in semi-arid watershed regions and recommended that for sustainable land and water management in areas adjacent to large dams, dynamic governance is needed to achieve it in transparent and fair manner. Tortajada, 2015 signified dams as an indispensable component of development. The study focused on the role of hydropower as renewable energy and its potential importance in regional development if managed effectively and properly. As the global dynamics of food, water, energy and trade has revamped the role of large dams, thus to avoid unnecessary social and environmental costs of these water structures, improving project planning and implementation is fundamentally important.

Biswas, 2004 argued that as we live in a heterogenous world with varying level of technological, cultural, social and environmental conditions, so no single solution is applicable to all the dams on the Earth. Every dam needs a unique solution as per the conditions of region or area where the dam is located. The main objectives of water development are poverty alleviation, regional income redistribution, energy efficiency, and environmental conservation. These objectives can be achieved by a systematic approach and case-specific solutions along with other alternatives such as rainwater harvesting and ground water recharge. Foudi et al.2023 suggested that in order to understand and prevent the conflicts related to dams, it is necessary to identify trade-offs between traditional and new NCPs as well as distributional impacts.

Thatte, 2011 studied the impacts of Koyna Dam in India and concluded that it has provided 200 times more profits to the local population than its adverse impacts. The author further argued that the Koyna dam proved to be an example of eco-friendly venture and not eco-destructive. For dams in general, the study recommended that for rationale decision-making regarding future dams it is imperative to learn from previous mistakes and to avoid repeating the same.

Shah & Gibson, 2013 assessed large dam construction in India and developed 12 set sustainability criteria for identifying potentially desirable options and monitoring implementation for infrastructure to be developed for water-energy-food nexus in India. The study further suggested that for sustainable considerations and better trade-offs regarding large dam development in India, a multi-jurisdictional and multi-stakeholder' engagement approach is required to identify and compare the potentially appropriate river basin infrastructure.

Erlewein,2013 explored the limitations of Environmental Impact Assessments for hydro projects in the state of Himachal Pradesh (India). The study concluded that current practice of conducting environmental assessments has several shortcomings. The author suggested that Politicians, Planners and Public should be provided the information about the environmental and socio-economic implications of cascade dam construction and it might lead to policy changes to avoid, mitigate adverse impacts of hydropower development in Himachal Pradesh and also to use the existing potential river basins in better way.

Scudder, 2011 pointed out that Project authorities or other agencies should institutionalize the necessary credit facilities while implementing resettlement plan for the people displaced due to large dam construction. Jain & Agarwal,2016 highlighted that more dams are needed to meet the demand of rising population in India and for that optimum regulation policy for all reservoirs is essential. Trussart et al.2002 reviewed the effectiveness of mitigation measures that are implemented to avoid or reduce the adverse impacts of dam construction. The study highlighted that there is need on part of hydropower industry to put more resources to monitor environmental and social mitigation measures adequately and the results of post project studies should be systematically fed and used for project planning and Impact assessment process.

Sharma & Rana, 2014 found that before sanctioning any other project in the region, there is dire need to consider equity, efficiency, participatory decision-making, sustainability and accountability and making the locals aware about their rights and environment. Diaz et al.2023 explored the impacts of 33 large scale dams on livelihoods of people in Global South. The research found that these dams have negatively impacted the social, natural, human and financial capital but have positive impact on physical capital. Further it is recommended that Policy makers and Practitioners should allow local people participation in decision-making to ensure equitable and just processes of hydro projects. Whenever a dam is to be built, government must ensure the Environment and Social Impact Assessments with improved designs and implementation.

Beck et al. 2012 examined that the role of affected individuals and political will as well as awareness about environment are the fundamental approaches for sustainable dam development. Kumar & Thakur, 2017 illustrated that in order to benefit and harmonize all interests, people's participation in decision-making and proper functioning of grass root democracy is the key to minimize the miseries of affected and to avoid the delay in completing the projects. Tilt et al.2008 addressed that for long term sustainability of dam projects, conducting proper social impact assessments and to develop strategies which address the concerns of local population is essential.

IEA, 2006 studied the resettlement and rehabilitation plan of Uri Power Project, India which is a good example of timely and proper execution and implementation of Resettlement and Rehabilitation Plan, protecting the archaeological sites. Arthur et al.2021 illustrated the case of Metolong dam, Lesotho for Protection of Archaeological site (Rock Art) by implementing Three R's strategy i.e. recording, researching, and (where essential and possible) removing (with suitable provision for long-term after care by way of storage, display, and curation).

Rana et al. 2007 examined the socio-economic impacts of Dams in Uttrakhand Himalyas and presented an example that how better trade-offs by negotiations with Locals can be helpful to resolve the conflicts. Dutka-Gianeli, 2022 explored how Adaptive Capacities and strategies by local communities can be useful for better livelihood in case of Dams in Amazon basin.

Karami & Karami, 2019 presented a Key Dams Sustainability assessment checklist that can be used for management and building of new dams. Gyasi et al. 2018 highlighted that Empirical studies are important to be carried out to ascertain whether the perceptions of people about dams are reality or not, so that mitigation measures can be put in place.

Kirchherr, 2016 analysed that more research should be carried out urgently on the social impacts of dams as dams' impacts go beyond the resettlement areas which was studied by 90% of previous literature. Shaktawat & Vadhera, 2020 discussed that for sustainable development of hydropower, risk management is essential and for future research, FUZZY hybrid and ANN is suggested. Aung et al.2021 examined the potential impacts of future hydro projects in the region and suggested that to create long term benefits, Social Life Cycle Assessment of Dams should be applied.

Brown, 2008 explored the usefulness of IDAM as a tool to understand how dams affect human and ecological systems, for consensus-building and appropriate and required decision-making. Mortey et al.2017 emphasized that for assessing proposed or existing hydro projects, multi-criteria analysis is valuable as it offers qualitative as well as quantitative assessments of these projects. Voegeli et al.2019 reviewed and found that for understanding interlinks between multiple aspects of hydro projects, Causal Diagrams can be used by decision-makers and concerned stakeholders as supportive and guidance tools.

Tullos et al.2009 discussed that to study the synergistic and integrated effects of biophysical, socio-economic and geopolitical components of dam construction, a collaborative and holistic approach is essential to adopt. Pradhan& Srinivasan,2022 found that Dams adversely affects the water security in India through several pathways. To reduce this adverse effect, dams should be designed and developed as Socio technical irrigation system and more empirical research in the field is required to establish fact-based evidences. Aledo et al.2015 recommended that Causal Maps can be used for assessing Ex-post social impacts of dams to find the underlying causes for negative impacts and the insights thus can be used for mitigating and avoiding these impacts.

Mishra et al.2024 preferred a balanced approach and holistic development strategies for sustainable energy harnessing and conservation to push future dams in Indian Himalayas towards greater environmental and social sustainability. Mudita & Sherly, 2023 discussed that water management policies in India are large dam centred, so we need a path that can conserve water and alleviate water scarcity by implementing cost - effective, eco-friendly and socially acceptable measures.

Bhatia, 2008 highlighted that dam assessment is a complex task, so indirect and induced economic impacts of dams should not be neglected while evaluating full development impacts of dam projects. Cestti &Malik, 2012 pointed out that Indirect Economic impacts of dams are equally important as direct impacts in dams impact assessment process. Schafer et al.2018 suggested that in order to gain more knowledge of large dams and their benefits, understanding the socio-economic impacts of these projects on women and children should be emphasised.

1.3.2 Studies on Dam Failure/Dam Safety

Azizi et al.2021 found that due to land use changes after the construction of Ekbatan Dam, the basin is more prone to flooding in future. To prevent flooding there is need to manage the vegetation cover in the catchment and extending dry lands by increasing agriculture and gardens. Ge et al.2020 asserted that Dam break can cause huge economic losses, thus suggested the Economic Risk Criteria which can be used to determine the dam risk levels and to check, if measures to mitigate risks should be taken or not. Krinitzsky & Hynes, 2002 recommended that for remediating an old dam, liquifiable alluvium beneath upstream and downstream portions of dam should be removed and replaced. As found after the Bhuj Earthquake, all alluvial foundation soils, must be evaluated over the full area beneath a new dam.

Sharma & Kumar, 2013 stated that for mitigating dam break risk, emergency planning and effective warning system are needed to be implemented with the help of local authorities and adequate public information and participation. Apart from it, safety control measures at dam site, rescue and relief measures in downstream are also essential. Erfeng & Ziyang, 2008 highlighted the need for the development of effective database for dam safety monitoring, multi-dimensional model plays an important role.

Naryan & Bueno, 2021 highlighted the importance of Comprehensive Risk assessment of all the large dams in India under phased DRIP programme by bringing and aligning people, processes and policies together.

Cleary et al. 2015 put forward a Prototype Risk Framework that can be used to analyse the impact of inundation behaviour which is different for landslip and piping failure mode. The study showed that flow rates in piping failure are smaller than the much larger landslip failure. Tsai et al.2019 found that during the development of Probabilistic Inundation Mapping for dam failure induced floods, the quality of DEM directly influences the prediction of flooded area. Hooshyaripor et al. 2017 pointed out that in dam break risk management reservoir's geometry must be considered because reservoir's capacity and length affect peak discharge and time of peak outflow. Moreover, lower side slopes create more catastrophic dam break flood wave.

Mehta et al.2020 suggested that in order to improve preparedness for dam failure risk, evidence-based risk communication strategy can be used which helps to support community knowledge of potential dam failure. Borgohain et al. 2019 claimed that in order to minimize losses of dam break floods, sustainable flow management and timely communication of warnings about water release, flood alerts can be given using mobile communication (bulk SMS system) to the villages likely to be impacted by floods. Salleh et al. 2024 affirmed that for reducing human catastrophe and socio-economic impacts of flood disasters due to dam failures, an appropriate risk management framework and empirical study should be undertaken to reduce dam break related risks.

FEMA, 2017 underscored the importance of Proper coordination among all stakeholders (government, community agencies, dam owners, at risk population) is important for most effective risk reduction and through all the phases of it (pre, during and post) dam failure. As every dam failure creates a unique and dynamic environment, so all strategies, frameworks, plans should also be framed accordingly. Khanm et al. 2023 brought out a Community Based Disaster Risk Management is proposed which prioritizes understanding the community perception and this framework will help in understanding the preparedness intentions and related perception factors.

Madnor et al. 2019 emphasized that community participation, multi-tier risk governance and role of local mangers in providing knowledge of unique local context is key to effective decision making and to be better prepared for dam related flood disasters. Samsuddin et al.2023 put forward an approach which call attention to the relationship between socioeconomic determinants and suggested that preparedness intention for dam failure flood risk vary depending upon the unique environment.

Muda et al.2023 proposed a Disaster Risk Reduction approach is and for this approach community participation and multi-agency involvement is significant. Moreover, an integrated programme involving agencies, dam owners and community leaders reduces the risk to the affected people. Rahsidi et al.2017 suggested that for dam safety, continues involvement of community is very important to ensure effectiveness of Early Warning System. Bashar et al. 2023 suggested that effective disaster management, stakeholders' involvement, regular monitoring and inspections of dam's structures are necessary for sustainable dam safety.

Muda et al.2020 proposed Dam Related Disaster Framework for emergency preparedness and to minimise loss downstream due to dam break and it works on the joint and coordinated community approach to face the disaster. Sen, 2021 recommended that developing a future regional database of water resources and events like droughts and floods is essential for dam reservoirs management in wake of climate change impacts.

Sissakian et al.2019 found that to have a safe dam and dam siting, geological investigations at different levels of dam are prerequisite. Furthermore, dam site, structure of dams, foundation and reservoirs should be covered under geological investigations. Ge et al.2020 put forward that Set pair analysis and cloud method is applicable and reliable to evaluate risk of potential dam breach and its environmental impacts.

Zhong et al.2021 asserted that in order to improve further developments in embankment dam breach modelling, prediction accuracy of breach parameters such as width and depth is necessary and for that, information on breach parameters of actual dam failures should be collected. Talukdar& Dey, 2019 suggested that the particles migration which starts piping can be prevented by proper use of drains and filters particularly in earthen dams. Hanson et al.2005 pointed out that role of head cut erosion in overtopping failure is very important, it points the need to predict the rate of head cut erosion in embankment overtopping which is further influenced by certain soil material properties.

Shah&Kumar,2008 highlighted that Volume of water stored in the reservoir is a strong indicator of safety hazard of dams but height of dam has no connection with the volume of stored water as data of 13000 large dams across the globe was analysed. Dhiman & Patra, 2019 found that Previous dam failures shown that lack of quality control during dam construction is the cause of failures. For safety of earthen dams, soil properties need to be controlled within the designed limits. Also, for estimating peak discharge, average breach width is an important factor in case of Indian dam failures.

Wieland & Fan, 2004 underscored the importance of using consistent Risk-based seismic design criteria for new dams, reassessment of seismic safety of existing dams is recommended. Roulo &Pichuka, 2022 recommended that to prevent dam disasters, advanced risk management modelling techniques, regular inspections and better building practices are required. Pichuka & Roulo, 2024 pointed out that in wake of climate change, better maintenance and management of dams and reservoirs in Godavari River basin is required as the magnitude and count of extreme events will intensify in future. Harsha, 2019 stated that Decommissioning is also an alternative for aged dams and research site and reconstructing fresh water storage structures is recommended.

Perera et al.2021remarked that for aged dams, frameworks and protocols that can accelerate the dam removal process are required. Wieland,2010 suggested that large dams with high damage potential in high seismicity areas and abnormal behaviour must be equipped with strong motion equipment. Wieland, 2020 found that in most dam types, fault movement in dam footprints is the critical seismic hazard and if there can be no change in dam site then conservatively designed earth core rockfill dam is recommended. Lemperie, 2017 recommended two spillways structure to increase dam safety and flood mitigation.

Naryan et al.2022 highlighted that several aged dams in India have several deficiencies and their rehabilitation is important for dam safety and sustainability. Project DRIP launched by government has successfully rehabilitated 223 dams in 7 states. PIB, 2024 recommended if dams' safety features, structures are maintained properly by carrying out timely repairs, the detrimental effects of aging can be reduced. Damle, 2021 remarked that dam break analysis is the basic need to create a Risk based Decision making system, but in India there are no set mandated standards and uniformity on how the dam owners carried the dam break analysis. Wang et al.2023 put forward a Dam Failure Risk Analysis using Bayesian method and Causal Loop Diagrams to present a demonstration of dam failure paths based on evidences that can help in decision making.

Fluxia-Sanmartin et al.2018 mentioned that by using input hydrology, flood wave and its consequences on the population and assets at risk can be calculated. This information will help dam owners in decision making regarding dam safety. Fluxia-Sanmartin et al.2019 indicated that for long term dam safety adaptation and decision-making support, there is need to consider the new climatic change scenarios while conducting dam failure risk analysis in the long term. Marche & Robert, 2002 pointed out that for managing dam failure risk, various methods can be used but the failure analyst should understand which method will effectively minimize the risk associated with a particular dam.

Qin et al.2022 stated that dam operation and safety depend on hydrology regime, so there is need to regulate dam operations in adaptation to changing climate and consequent altered hydrology. Sivapriya & Anna Sherin, 2022 found that dam profile and properties should be investigated in detail to find the cause of dam failure. Li et al.2023 emphasized that the impact of climate change on dams should be completely examined during all the stages of dam, for sustainable dam safety.

Sivasuriyan et al.2022 put forward the significance of Structural Health Monitoring of dams and affirmed that the changing environment, climate and pollution will have a significant impact on dam structures. So, Structural Health Monitoring of dams is critical area of research to know the condition of dams' structures for lifetime. Tosun & Ardebli, 2024 recommended that Seismic risk analysis of high dams is imperative as dams situated near fault segments possess high risk potential during earthquake. World Bank, 2020 asserted that Dam failure risks are design and situation specific, so while managing such risks, there is need to consider unique set of parameters depending on the design and site of a particular dam.

1.3.3 Studies on Ranjit Sagar Dam

Sharma (2019) studied displacement and resettlement due to Ranjit Sagar Dam using Mixed-Method approach and found that instead of having any improvement in the quality of life the project pushed the population into the risks of impoverishment.

Brraich & Saini, (2015) assessed the water quality of Ranjit Sagar Wetland using Physico-chemical parameter and found that presence of nutrients likes sulphates, phosphates, nitrates, nitrites and silicates in sufficient quantities, which are helpful to enhance the growth of aquatic flora and fauna in the wetland and found that water of wetland is not fit for drinking.

Kumar (2018) analysed the Hydrobiological parameters of Ranjit Sagar wetland and found that Ranjit Sagar Wetland is highly productive and clean, but this wetland also faces serious threats like siltation from catchment area, deforestation, sand and stone mining, domestic sewage pollution, agricultural runoff and various other anthropogenic activities.

Tripathi et al.2024 found a notable 36% reduction in dry season discharge (April-May) at the river outlet since the construction of the Ranjit Sagar Dam reservoir. Water availability has decreased dramatically, shrinking from 17.35 km^2 to only 3.46 km^2 after 2000. This reduced river flow has encouraged the growth of riparian vegetation in the floodplain. Additionally, the researchers have observed increased human encroachment in the area, leading to ponding and other geomorphological changes over the last decade. The research further emphasized that there are significant effects of reservoir construction on river systems and thus highlighted the importance of implementing sustainable management practices.

1.4 Research Gap

Study of socio-economic impacts of dams is crucial in comprehending the nexus of complex impacts that dam construction and operation have on communities, local economies and national development. As far as social and economic implications of dams are concerned, there has been remarkable research carried out, yet several gaps exists and to improve the outcome of dam projects through informed and better policy/decision-making these gaps need to be addressed. These gaps generally revolve around the convolution of socio-economic transformation induced by dams, long term impacts on various social groups within a community or compared to other community and cause-effect dynamics surrounding dam impacts. Here we present the main gaps in the socio-economic analysis of dam projects:

1. Lack of empirically verified findings regarding diverse perceptions of different demographic groups (such as Occupation and Age) within a community for socio-economic impact of large dams in general and Ranjit Sagar Dam in particular. These perspectives are essential for developing sustainable management strategies. Thus, more research is needed on the equity of resource distribution and how dam projects affect income disparities within and between communities.
2. Limited attention has been given to study the educational, occupational and income disparities between upstream and downstream region of Ranjit Sagar Dam Watershed. The long-term consequences of such large-scale water infrastructures on social mobility, education, income inequality, and educational practices are yet to be thoroughly understood. These studies are pre-requisite to find the causes of regional disparities and consequent adaptive measures to lessen these disparities.
3. Impacts of dam construction such as displacement and resettlement are well documented but there is lack of comprehensive studies that examine the impacts during operational phase of a dam. How these communities fare over time in terms of livelihood, access to resources and infrastructural facilities. There is a need for research involving such studies.

4. No research covers the spatial mapping of physical resource base of Ranjit Sagar Dam region and its watershed. These studies are imperative from Integrated Watershed management policies and planning.
5. There is lack of studies focusing on potential dam failure risks to Ranjit Sagar Dam and analyzing the perceptions of community regarding dam safety. These studies are significant in developing community-based dam risk management policies.
6. Lack of frameworks which studies large dams as part of its watershed and exploring its physical resources, spatio-temporal and demographic variations in perceptions of community for socio-economic dynamics of large dams including dam failure risk and dam safety.

1.5 Statement of the Problem

The uneven spatial distribution of physical resources across the dam's watershed creates disparities in access and utilization leading to dam induced adverse socio-economic impacts of varying spatial and temporal scale. Yet little research has systematically examined these patterns and their implications. There is a pressing need to investigate how resource distribution, socio-economic disparities vary spatially and temporally within different regions of dam's watershed, potential risks that can lead to dam failure and effectiveness of dam safety measures interact to shape vulnerability and resilience within the study region.

1.6 Research Questions

- How are the physical resources spatially distributed within the study region?
- Is there a statistically significant difference in income level between upstream and downstream residents?
- How do the major socio-economic impacts vary across demographic groups of upstream and downstream region during constructional and operational phase?
- What are the potential risks that can lead to dam failure?
- How various demographic groups perceive the adequacy of existing dam safety measures?
- Which mitigation measures can be adopted to reduce the adverse impacts?

1.7a Objectives of Study

- To find the Physical resource base (Topography, Geology, Soil, Riparian vegetation, land use land cover) of the area under study.
- To identify the major socio-economic impacts in upstream and downstream region of Ranjit Sagar Dam during constructional as well as operational phase.
- To evaluate the dam failure risks and dam safety measures.
- To suggest impact mitigation measures.

Based on the objectives of the study, following hypotheses are proposed

1.7b Hypotheses

H_{11}: There is a significant difference between mean income of upstream and downstream residents.

$H_{12:}$ Occupation, age and education have a significant association with impact on livelihood, community and infrastructure.

$H_{13:}$ Occupation, age and education have a significant association with adequacy of dam safety measures.

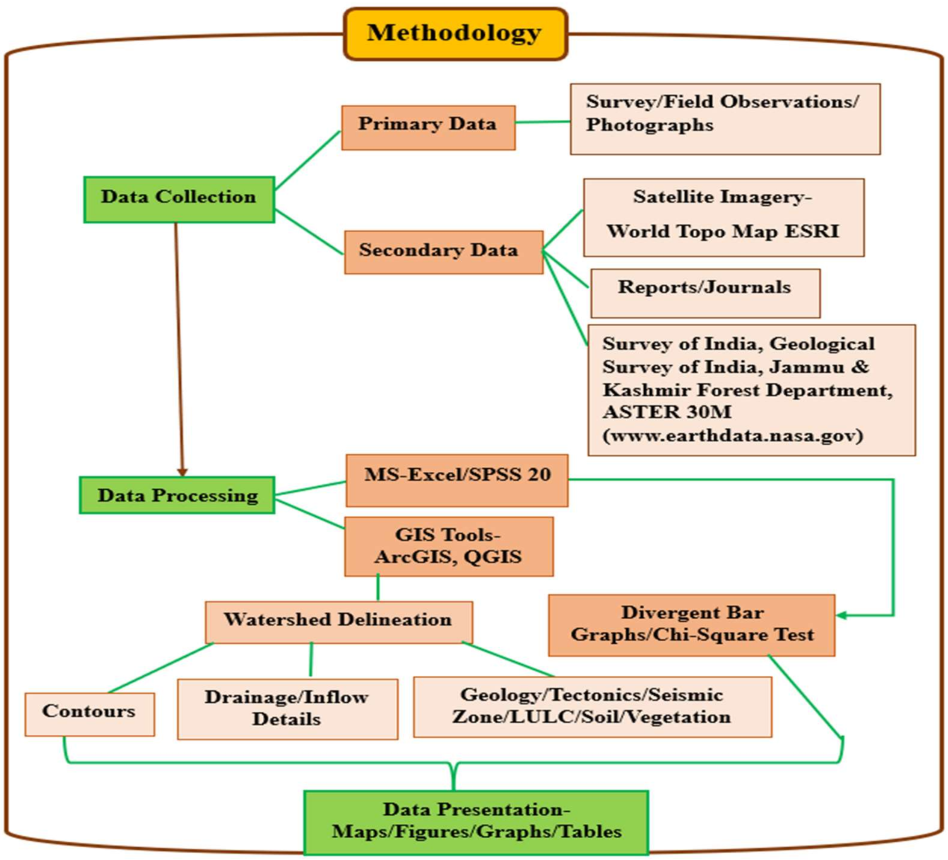
1.8 Methodology

This study employs an exploratory research method approach to examine the spatial and temporal dimensions of socio-economic dynamics induced by Ranjit Sagar dam combining remotely sensed data, quantitative surveys and field observations. A Case Study research design has been chosen to have an intensive understanding of the spatial and temporal patterns of various social and economic impacts generated specifically by Ranjit Sagar dam and the interaction of these impacts with physical resource, dam failure risks and dam safety measures. Figure 1.12 illustrates the schematic representation of methodology used for this study.

Sections given below presents all the steps including data collection, data analysis techniques, sampling, study area description and data presentation.

Fig. 1.12

Flow chart for research methodology



1.8.1 Data Collection

For this study, the methodology applied includes both primary and secondary sources of data so that spatial and temporal aspects of study area can be evaluated thoroughly.

(i) **Primary data:** Under this section, data acquisition is done by conducting field observations and Sample Survey where structured Questionnaire is used as a tool to interview respondents in sampled households for comprehending the attitudes and opinions of project affected people regarding the socio-economic dynamics induced by the dam and to evaluate how these opinions vary spatially and temporally. Moreover, satellite images are used to have an overview of physical resource distribution in the study region.

(ii) **Secondary Data:** Data is sourced from various sources such as international documents, national reports on dams, reports from government departments, newspaper articles, Journals, official documents of Ranjit Sagar Dam and previous studies on the Project.

1.8.2 Study Area

For this research, Ranjit Sagar Dam watershed is selected as the study area which is a part of Ravi River Basin. Ranjit Sagar Dam is a mega hydraulic structure built on Ravi River for multi purposes such as power production, irrigation and flood control (Paunikar & Sharma, 2022). This dam is an interstate hydro project and lies at the boundary of J&K and Punjab near a gorge at Thein village of Kathua district (J&K). Ranjit Sagar Dam watershed covers parts of Kathua district (J&K), Pathankot District (Punjab) and Chamba district (H.P) (Table 1.6). Its coordinates are $32^0\ 26^/30^{//}$ North latitude and $75^0\ 43^/44^{//}$East Longitude (Rayaz et al. 2008). The dam has a height of 147m and is sixth highest dam in India (NRLD, 2018). The total area of Ranjit Sagar Dam Watershed is 1360.57 Km^2 (Table 2.4).The present study delineates the watershed boundary of Ranjit Sagar Dam Watershed from the catchment of Ravi River Basin as demarcated in Map 1.1. Further, on the basis of altitude and drainage, a total of 12 villages has been identified for doing survey. Out of these 12 villages, six villages fall in the upstream region of Ranjit Sagar Dam and six villages fall in downstream region of the dam. Upstream villages include Mahanpur, Bera, Poonda, Plakh, Thara Uprala and Dhar Kalan. Downstream surveyed villages include Basantpur, Danna, Hote, Thara Jhikla, Kot and Kamwal as shown in Map1.1.

1.8.3 Sampling

For this study, we collected data from 528 sample households lying upstream and downstream region adjacent to the Ranjit Sagar Dam reservoir in Kathua (J&K) and Pathankot (Punjab) districts. To select 528 sample households (321 upstream and 207 downstream), the multi-stage sampling technique was applied. In the first stage, Kathua district from J&K and Pathankot district from Punjab state were selected, as these districts were mostly affected due to reservoir inundation and consequent submergence. In the second stage, 12 villages (6 upstream and 6 downstream) were selected on the basis of altitude and watershed (Map 1.1). After that, taking 10% of total households of each village, required sample size was allocated to selected villages and initial sample size was finalized 523 which was increased to 528 due to availability of more willing participants. Then, sample households were selected using random sampling method to collect primary data. A multi-stage random sampling design was adopted due to the large size and spatial dispersion of the study population. This approach enabled efficient data collection by selecting sampling units in successive stages while maintaining randomness at each stage. The design ensured adequate representation of heterogeneous sub-populations and reduced logistical constraints and costs (Kaplan, 2025).

Map 1.1

Study Area

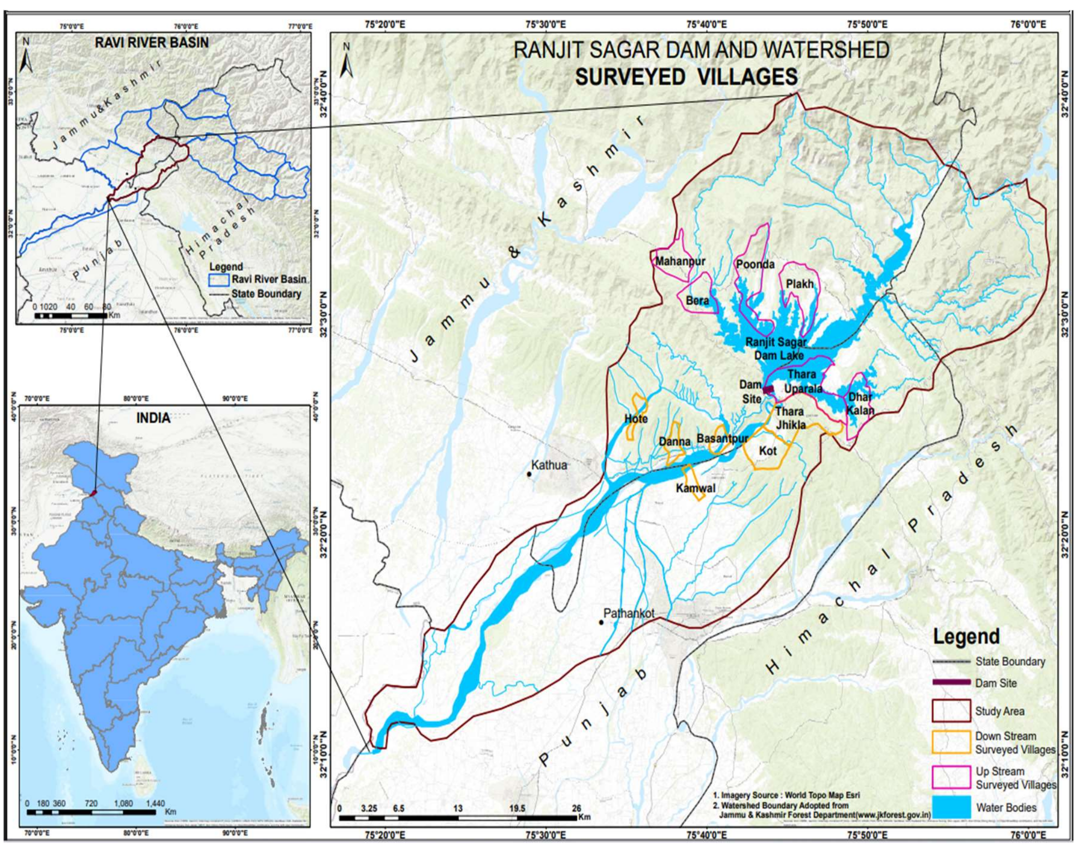


Table 1.6

Ranjit Sagar Dam Watershed: District wise Area

Name of District (State)	Area under watershed (in km^2)	Percentage of total area (%)
Kathua (J&K)	619.31	45.52
Pathankot (Punjab)	576.66	42.38
Chamba (H.P)	164.60	12.10
Total	1360.57	100.00

Source: Author's work

1.8.4 Data Analysis Techniques

For the present study, exploratory research method approach is used where combines both quantitative as well as qualitative data are gathered for the case study. Thus, data analysis and interpretation are grouped as follows:

(i) Quantitative Data Analysis

Data collected through survey using questionnaires was tabulated, processed, and classified using MS-Excel. For showing the survey responses theme based Diverging Bar Graphs and corresponding data tables are also created in MS-Excel. To corroborate the findings, hypothesis testing is also done using the SPSS software. An independent samples t-test has been employed to assess whether the mean income differed significantly between upstream and downstream residents. The hypothesis states that a significant difference exists in mean income between two groups. A Chi-square test of independence has been applied to examine the association between occupation, age, education and respondents' level of agreement for impacts on livelihood, community, infrastructure and adequacy of dam safety measures. The hypothesis assumed the presence of a statistically significant association between the variables. Further, for spatial mapping of physical resource base and dam failure risks, various maps are also created using QGIS and Arc GIS software.

(ii) Qualitative Data Analysis

The responses of various focus groups such as Village Sarpanch's, Chowkidar's, Dam's engineers and Chief engineers have been analysed and interpreted under different themes. Also, to have an in depth understanding of respondent's feelings and opinions, their statements are recorded and interpreted accordingly. To have a real time situation assessment, numerous photographs collected during field observations are interpreted to authenticate the views of respondents.

1.9 Overview of Ranjit Sagar Dam

The study area identified is Ranjit Sagar dam. The Ranjit Sagar Dam, also known as Thein Dam, is part of a hydroelectric project managed by the Punjab Irrigation Department on the Ravi River, straddling the border between Jammu and Kashmir and Punjab (Gupta et al.2020). It is a gigantic multipurpose river valley project built on river Ravi in the region of Shivalik foothills. It is in a gorge near village Thein of J & K and as such it is also known as Thein Dam (Sharma, 2019). It is 24 km upstream of Madhopur Headworks and the dam is approximately 30 km from both Pathankot in Punjab and Kathua in Jammu and Kashmir (Jain et al.2018). Ranjit Sagar Reservoir is spreading in an area of 8700 km^2 (Table 1.7) with 60% of it located in Jammu and Kashmir and rest of its area falls in Punjab and Himachal Pradesh (Gupta & Das, 2005). Ranjit Sagar Dam (Thein Dam) Project is one of the largest multipurpose river valley projects on the river Ravi which houses four generating units of 150 MW each with total installed capacity of 600 MW (Government of Punjab, 1983) (Plate 1.1& 1.2). It has firm power of 162 MW at 100% load factor. 4.6% of energy generated is supplied free of cost to H.P. and 20% of energy generated is to be supplied to J&K at the generated cost at the Bus Bar (PSPCL,2026). The Ranjit Sagar Dam Spillway has several distinct technical characteristics that have been rarely incorporated in hydroelectric projects across the country. With Multiple energy dissipation system and Aeration Gallery as unique features, the spillway stands out in terms of design and functionality (Department of Water Resources, (Punjab), 2021).

Table 1.7

Ranjit Sagar Dam: Features

Features	**Numbers/Facts**
Catchment area	6086km^2
Reservoir area	8700km^2
Gross storage capacity	3280million cum
Live storage capacity	2344million cum
Maximum Height	147m (6th highest in India)
Total installed capacity	600MW
Dam type	Earth core-cum-gravel shell dam
Turbine type	Vertical Shaft Francis (2nd biggest in India)

Source: Official Documents on Ranjit Sagar Dam; Government of Punjab, 1983

Plate 1.1

Source: Google, 2024. Aerial View of Ranjit Sagar Dam (Satellite Imagery). Google Earth Pro. (https://earth.google.com/web/@32.44365555,75.73401893,2403.85395276a,0d,35y,0h,0t,0r/data=CgRCAggBQgIIAEoNCPwEQAA)

Plate 1.2

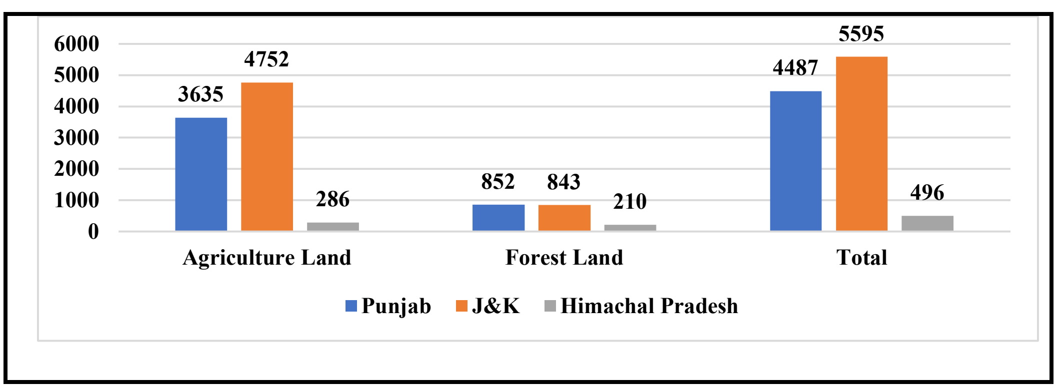
Source: Field Work, 2024   A view of Ranjit Sagar Dam Embankment and Reservoir

1.9.1 Details of Land Acquired/Affected Families/Villages Due to Ranjit Sagar Dam Construction

As per records, a total of 10578-hectare land (Figure 1.13) was acquired during construction of this dam which affected 63 villages in U.T of J&K, Punjab and H.P. About 4153 families from all the three states got affected during the process (Figure 1.14). Additionally, in 1999, approximately 13,000 individuals were employed in dam-related occupations. In contrast, as of the present day, only about 2,000 individuals are employed in positions associated with the Ranjit Sagar Dam.

Figure 1.13

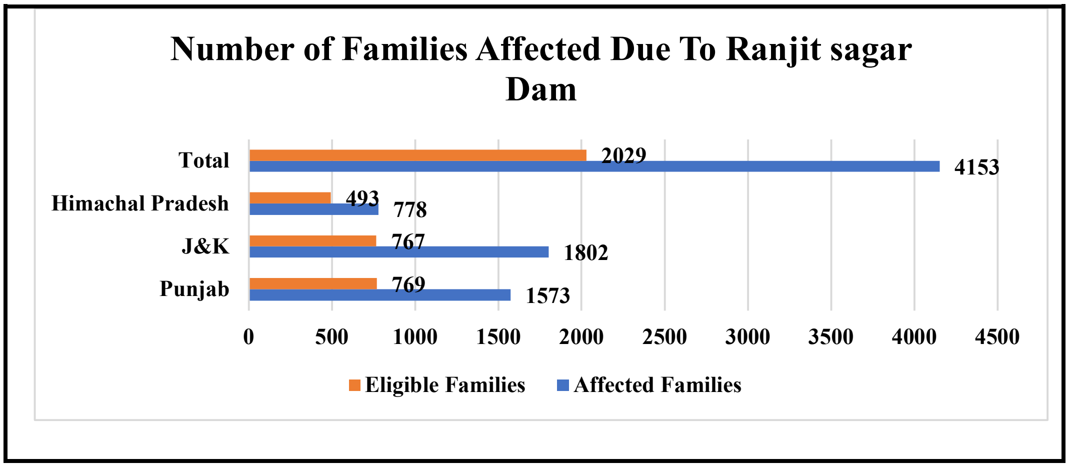
Ranjit Sagar Dam: Land Acquisition (in Hectares)



Source: Compiled by Author from Official Documents on Ranjit Sagar Dam

Figure 1.14

Ranjit Sagar Dam: Details of Affected Families



Source: Compiled by Author from Official Documents on Ranjit Sagar Dam

1.10 Significance of the Study

This study will contribute vitally to the integration of dams in the sustainable development of the study region particularly and water resource management in general due to several reasons:

- *Narrowing the Regional Disparities:* Understanding the disparities in Occupation, Education, Income level of upstream and downstream region of a dam is crucial for sustainable development of both the regions. By analysing these aspects, our study can inform various strategies targeted towards reducing these inequalities.
- *Short Term and Long-Term Sustainability of Dams:* To comprehend the Socio-economic dynamics induced by a dam during construction and operational phase can reveal the temporal variations in the spatial distribution of dam's impacts. By analysing the positive and negative impacts due to dam at its different stages can help formulating plans for improving the short term and long-term social and economic sustainability of dams.
- *Dam Safety:* In wake of climate change and increased cases of dam failures globally, it is extremely necessary to evaluate the dam failure risks and dam safety of these water structures for social and environmental protection of

communities and resources. Our study assesses the potential risks of dam failure to Ranjit Sagar dam and adequacy of Dam safety measures adopted, thus will contribute significantly towards the steps needed to be taken for integrated dam safety management.

- *Resource Management:* Exploring the distribution of physical resources such as soils, vegetation, land use land cover, geology in the study area surrounding Ranjit Sagar Dam can provide major insights to be considered for proper resource management in the region.
- *Policy and Planning:* By analysing how different demographic group perceive the impacts of dams can help identifying the social groups more benefitted by dam building and the ones who need more targeted interventions during decision-making and policy formulations so that the social conflicts surrounding construction of dams can be avoided.
- *Enhancing Scientific Knowledge:* By interpreting the interconnected patterns of different social, economic and infrastructural components and how the cause of one component has an effect on the other e.g. the changes in infrastructural components due to construction and operation of Ranjit Sagar dam can affect the overall well-being of communities residing in the vicinity of a dam will add to our understanding the cause effect relationship of different impacts due to dam. Moreover, how occupation influences the people's positive or negative views regarding dam construction findings will contribute to the existing scientific knowledge.

In general, this research on Ranjit Sagar Dam has vital inferences for making dams more sustainable socially, economically and their role for local, regional and national development.

1.11 Limitation of the study

- This study primarily relies on the perspectives of local households. However, it might be helpful to include viewpoints and suggestions from other parties like - governmental and non-governmental bodies. A diverse and comprehensive view could help in developing well-versed mitigation strategies.

- While the study touches upon various dimensions of the impact (livelihood, infrastructure, community), there might be other relevant variables not explored in depth. For example, the study might not extensively cover the psychological and social impacts on local women and children.
- This study specifically analyses the attitudes and opinions of respondents categorized based on demographic variables (occupation, age and education). However, gender-based analysis of perspectives is not considered.
- The study briefly touches upon the risks of dam failure in the context of climate change related extreme events such as flooding but does not deeply explore the potential impacts of climate change on dam safety. Understanding these impacts is essential for formulating adequate dam safety measures and strategies.
- While the study mentions community-level suggestive measures to be adopted for mitigating adverse impacts of future dams in the region, it may not delve deep into the effectiveness or challenges associated with community involvement in policy and decision-making. Understanding community dynamics and the success of such initiatives could provide valuable insights.

1.12 Chapters Layout

The current study will be divided into the following chapters

Chapter 1: Conceptual Framework and Methodology

This chapter will unfold the theoretical underpinnings of the concepts and theories with reference to displacement and resettlement, followed by the statement of problem, needs and significance, objectives and the research questions raised in the study. It will also explain the sources of data and methodology opted for conducting the study.

Chapter 2: Physical Resource Base of Study Region

In this chapter, a GIS based study has been done to study the topography, Geology, Soil, Drainage, Land Use Land Cover and Vegetation of the Ranjit Sagar Dam Watershed. Maps are created using ArcGIS Software. The study of physical resource base will provide essential insights for land use and water management policies in the watershed.

Chapter 3: General Information and Graphical Representation of Survey Responses

In this chapter, firstly, an attempt has been made to analyse the general information of Respondents (both Upstream & Downstream region) in detail focussing on demographics (Gender, Age, Education, Occupation, and Income) that influence the survey results. Following this, the survey responses are presented graphically showcasing the data in different visual forms.

Chapter 4: Socio-Economic Impacts Induced by Ranjit Sagar Dam in Upstream Region

This chapter presents a comprehensive statistical investigation into the opinions and perceptions of multiple stakeholders regarding the socio-economic impacts associated with Ranjit Sagar dam construction in the upstream region, focusing on both the construction and operational phases. The analysis categorizes the socio-economic impacts into broad themes—specifically, Impacts on Livelihood, Infrastructure, and Community.

Chapter 5: Socio-Economic Impacts Induced by Ranjit Sagar Dam in Downstream Region

This chapter explores the socio-economic impacts associated with Ranjit Sagar Dam in the downstream region focusing on both the construction and operational phases of dam by analyzing the perceptions and opinions of various social groups. The socio-economic impacts are grouped into wide-ranging themes -particularly, Impacts on Livelihood, Infrastructure and Community.

Chapter 6: Dam Failure Risks and Dam Safety Measures

This chapter proceeds with evaluating the potential risks of failure to Ranjit Sagar Dam based on the potential causes of dam failures in India and the history of previous dam failures. Also to explore how different demographic groups perceive the potential failure risks to Ranjit Sagar Dam and adequacy of dam safety measures, statistical analysis will be done.

Chapter 7: Implications, Recommendations and Conclusion

This chapter provides a comprehensive summary of the key findings, conclusion and recommendations derived from the research study on Ranjit Sagar Dam. It synthesizes the main insights and implications discussed in the preceding chapters and offers suggestions for future research directions, policy interventions, and community-based mitigation measures aimed at addressing the challenges and opportunities associated with management of adverse impacts induced by Ranjit Sagar dam.

CHAPTER 2

PHYSICAL RESOURCE BASE OF RANJIT SAGAR DAM WATERSHED

Mankind depends on various natural resources for its existence and assessment of physical resources of a region is essential as regional development and planning depends on the potential, challenges in utilising these resources and applicability of physical resources for other purposes significant for growth and development of humans (Balasubramani, 2018). Physical or natural resources include multitude of groups classified as agricultural, forestry, energy, water, minerals, soils which are produced due to different biological, ecological and geological processes and fulfil human needs (Bridge, 2009; Zhou et al.2018). A natural feature of the Earth's surface that integrates key resources like landforms, groundwater, soils, geology, forests, surface water, the lower atmosphere, and vegetation, all of which influence land use potential and the results of both historical and modern human activities (Shelar et al.2022).Similarly, to study the physical resources in the vicinity of large dams is imperative as better management of the natural ecosystems, their resources and services is prerequisite for making big water structures more resilient and sustainable by applying a balanced approach to integrate conservation of nature's resources and construction of large dams[1](McCartney et al.2017). This chapter examines the topography, soils, geology, Land use, riparian vegetation of Ranjit Sagar Dam Watershed Region. This spatial mapping of resources in the present study is based on GIS, Remote Sensing and Secondary sources. The methodology used for spatial mapping is represented through the flow chart in Figure 2.1.The chapter has three sections as given below:

2.1 First section investigates the Topographical, Drainage and Geological details of the study region.

2.2 Second section explores the Soil Types and distribution in Ranjit Sagar Dam Watershed.

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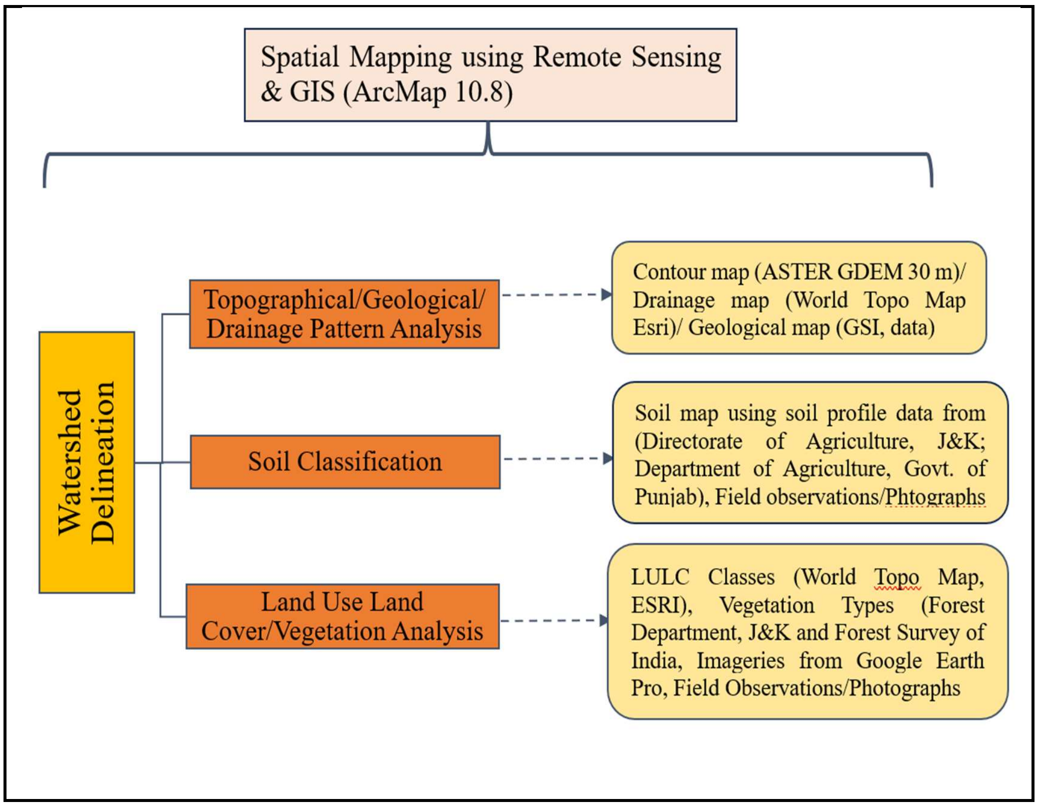
[1] https://iucn.org/news/water/201709/rethinking-role-nature-dam-planning-and-management

2.3 This section illustrates details about Land Use Land Cover Analysis and Vegetation of the Ranjit Sagar Dam watershed.

Figure 2.1

Ranjit Sagar Dam watershed: Spatial mapping and Flow chart of methodology



Source: Author's work

2.1 Topographical, Drainage and Geological details of Ranjit Sagar Dam Watershed.

2.1.1 Topographical Details of Ranjit Sagar Dam Watershed

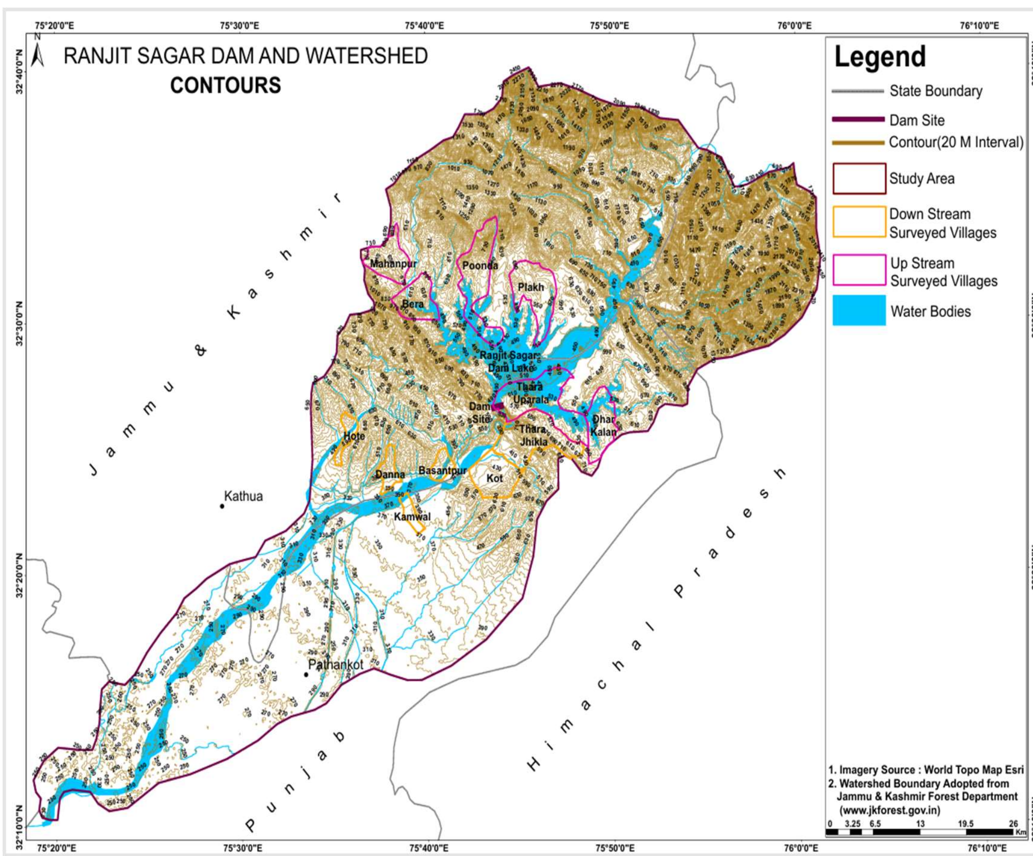
The landscape of the Ranjit Sagar Dam watershed has varied topography comprising the hilly tract in the upstream of the Dam and undulating plain and the flood plains of the Ravi River in the downstream region. The watershed spreads over Tehsil Basholi, Tehsil Mahanpur, and Tehsil Kathua of Kathua district (Jammu & Kashmir), Tehsil Dharkalan and Pathankot of Pathankot District (Punjab) and Tehsil Dalhousie of Chamba District (Himachal Pradesh) (Map 1.1).

2.1.1.1 Elevation

Elevation is the vertical distance from a point on the land surface to a reference point, typically the mean sea level (McVicar & Körner, 2012). Map 2.1 depicts the elevation of watershed through contours spaced at 20m interval. Contours are the imaginary lines which join the places of same elevation. Contour lines or isohypses are essential for representing relief quantitatively, elevation representation and for identifying morphometric features on a map (Gulibert, 2013; Kettunen, 2017). The study region is predominantly covered in forests and has rolling terrain (Sharma, 2019), with elevations ranging from 230 meters in S-W floodplains of Ravi in Pathankot to 2500 meters in N-W mountainous terrain of Watershed from where the Biani Stream rises (Map 2.1). The elevation decreases as one move southward.

Map 2.1

Ranjit Sagar Dam Watershed: Elevation and Slope



2.1.1.2 Slope

The upstream region of Ranjit Sagar Dam watershed has steep slope <= 34 meters and Ravi River flows through valleys and gorges[2]. The slope becomes milder as the river progresses downstream forming wider floodplains (Map 2.1). The region features flood plains with river-carved bluffs (Sharma, 2019).

2.1.1.3 Physiography of Ranjit Sagar Dam Watershed

The whole watershed comprises the Shivalik region which consists of Shivalik Hills and Piedmont plains. Shivalik hills covers the entire upstream region of Ranjit Sagar Dam and Piedmont plains spread over the entire downstream region of the dam watershed (Yadav et al.2015).

Shivalik hills: These are the youngest mountain and sub-mountainous ranges separated from Lesser Himalayas by Main Boundary Thrust (MBT). Geologically, these hills differ from other Himalayan ranges (Yadav et al.2015). Its elevation ranges between 600m to 2500m from MSL (Map 2.1)

Piedmont Plains: These plains lie south of Shivalik hills and also known as Kandi Belt. Seasonal streams (Khads) flowing from the hills have eroded these plains resulted in highly rugged and dissected terrain (Yadav et al.2015). The southern parts of this belt having elevation less than 300m from MSL are locally known as Sirowal Belt in Kathua district. As compared to the northern parts(Kandi belt) of Piedmont plains, Sirowal belt has homogeneous and fertile soil. On the contrary, northern part is having elevation from 300m-800m from MSL (Map 2.1). Its soil has high porosity and rocky debris carried down from higher mountain ranges and there is excessive drainage due to low water retention capacity. The northern parts of Piedmont plains are rain fed and have low agricultural productivity as compared to southern parts or Sirowal Belt which has suitable level of groundwater after dam construction on Ravi River (Singh & Bharti, 2023).

[2] Official Report of Office of Chief Engineer Ranjit Sagar Dam, Jugyal (Punjab).

2.1.2 Drainage in Ranjit Sagar Dam Watershed

A drainage map for a dam watershed illustrates the area that directs rainfall and surface water toward the dam's reservoir[3]. The drainage pattern in a system reflects the spatial arrangement of streams with in a specific area or region. The position, quantity, and flow directions of the streams in a given area are influenced by factors such as the slope, geological structure, rock types, tectonic activity, climate, vegetation, and other environmental characteristics. In the study area, the drainage pattern is dendritic, exhibiting a tree-like branching structure. This pattern suggests homogeneity and uniformity in the geological properties (Sharma, 2019; Singh et al.2014). This pattern forms in different structural and geological environments, such as mountainous and hilly regions like the Himalayas (Singh 1997). In Ranjit Sagar Dam Watershed, the dendritic or tree-like drainage pattern is most common, primarily due to the rugged and dissected topography of the mountains. The presence of this drainage system suggests that the soil and rock materials are homogeneous and consistent (Sharma, 2019). Further, the stream network as depicted in the Map 2.2 shows all the streams and rivers within the Ranjit Sagar Dam Watershed, their connectivity and flow direction towards the reservoir and Ravi River. Numerous seasonal streams locally known as 'Khads' drain the watershed region upstream and downstream region of Ranjit Sagar Dam Reservoir. These streams contain boulders, pebbles, sand and silt during monsoon (Mondal et al. 2021).

In the upstream region, Biani stream near Mahanpur and Nandi Khad near Bera village, Loai di Khad near Poonda village, Gurnol Nala near Plakh village and Karnal stream near Dhar Kalan and Thara Uparla village are the main tributaries draining the runoff into the reservoir thus contributing to the overall water flow towards the dam whereas Mangar Khad near village Hote, Tridwan di Khad joining Sukal Khad near Basantpur Village, Parwan Nala near Danna village, Salar di Khad[4] near Kot and Thara Jhikla villages are the major streams draining Ravi River downstream of Ranjit Sagar Reservoir (Survey of India, 1973).

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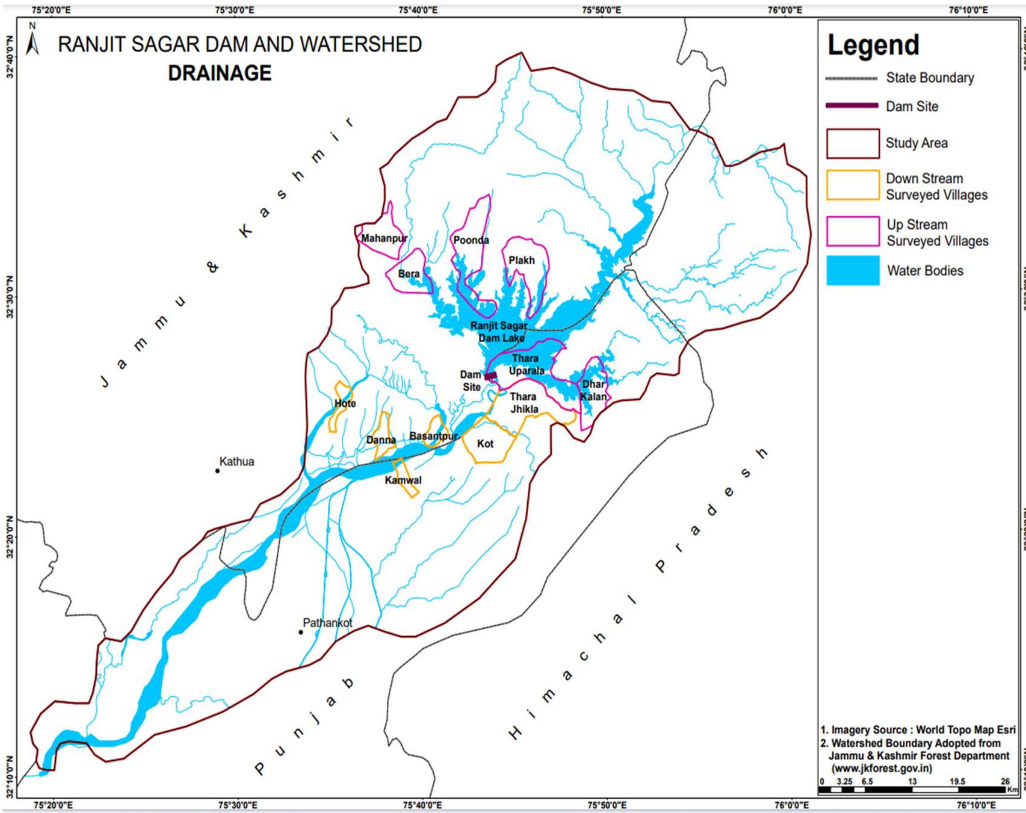
[3] https://www.usgs.gov/special-topics/water-science-school/science/watersheds-and-drainage-basins

[4] Official Documents on Ranjit Sagar Dam, Office of Tehsildar, Basholi (J&K)

Map 2.2

Ranjit Sagar Dam Watershed: Drainage Network



All these streams along with Ravi River carries lot of sediments due to steep slope and sedimentary rocks found in the upstream region of Ranjit Sagar Dam watershed[5]. Thus, these tributaries are the source of sediment load entering to the dam's reservoir. Essentially, this map shows the flow paths of water to the dam, helping dam engineers and planners to promote water resource management, environmental protection, and regional development strategies as discussed below:

- To identify potential flood risks, restricting construction in high-flood risk zones and suggestive mitigation measures such as flood control infrastructure, emergency response plans to protect communities and properties downstream.
- To assess potential water inflows into the reservoir to manage the dam's operation efficiently for better water storage, power generation and distribution.

[5] Official Documents on Ranjit Sagar Dam, Office of Chief Engineer, RSD, Jugiyal (Punjab)

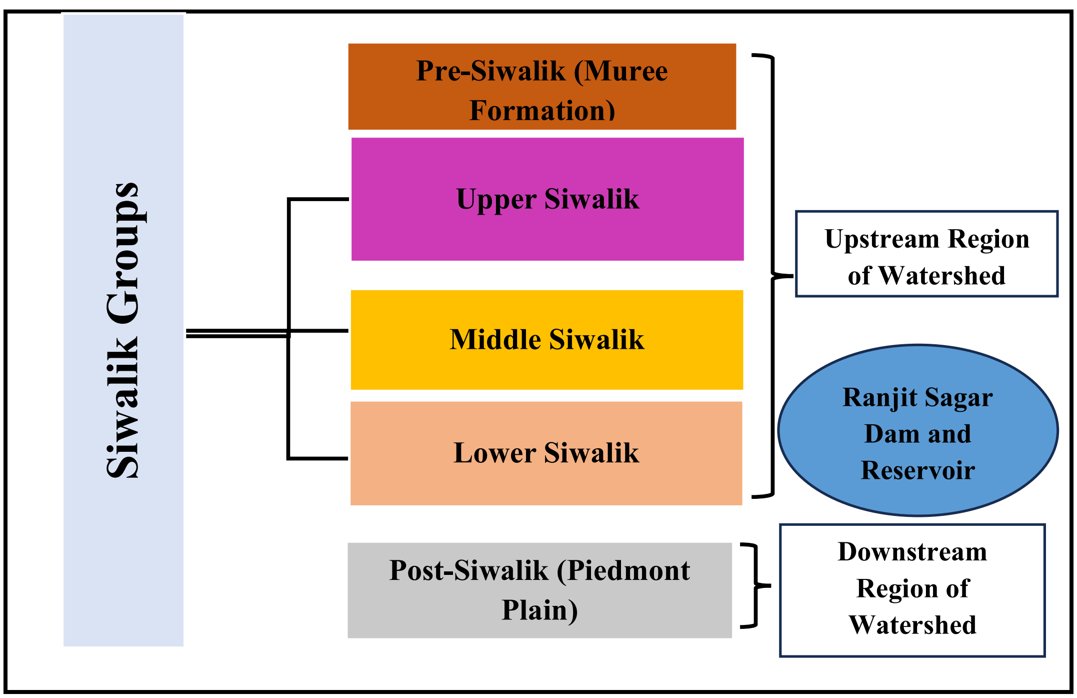
- To assess the sediment load by identifying areas with high erosion rate and better land use management by controlling development in sensitive areas and thus minimizing negative impacts on the watershed.
- To promote integrated watershed management, considering the interconnectedness of water resources, land use, and natural ecosystems. This includes fostering collaboration between government bodies, local communities, and environmental organizations to protect the entire Ranjit Sagar Dam watershed, ensuring its health and productivity for future generations.

2.1.3 Geological Details of Ranjit Sagar Dam Watershed

The region of Ranjit Sagar Dam watershed is characterised by the rocks of geologically young and tectonically vigorous Siwalik group (Map 2.3) (Fig. 2.2) formed during Middle Miocene to Middle Pleistocene (Nath & Nandy, 2021).

Figure 2.2

Ranjit Sagar Dam Watershed : Schematic Representation of Siwalik Group



Source: Compiled by Author

The Frontal Siwalik terrain in the vicinity of Ravi River and Ranjit Sagar Dam watershed is characterized by Upper Muree Formation in the northern parts followed by Upper Siwalik Group, Middle Siwalik group, Lower Siwalik Group and alluvial plain in the Southern parts of Watershed (Sharma & Choudhri, 2020). With Lower Siwalik in the South followed by Middle Siwalik and Upper Siwalik in the North, all these ridges lie parallel to each other. These comprises of rocks such as coarse sandstones, clays, sand rock and conglomerates (Tripathi, 1986) (Table 2.1). The region of Ranjit Sagar Project is seismically very active and lies on the regional anticline of Lower Siwalik hills (Geological Survey of India, 2016, p.6). Geology plays an important role in the functionality and overall stability of a dam's watershed as it controls the sediment load and transportation into the reservoir as well as downstream distribution of water and sediments (Grant et al.2013). Also, geological factors influence water quality of dam's watershed, dam safety and thus impacts watershed management (Hazbavi, 2018; Sissakian et al., 2020).

Map 2.3

Ranjit Sagar Dam Watershed: Geological Details

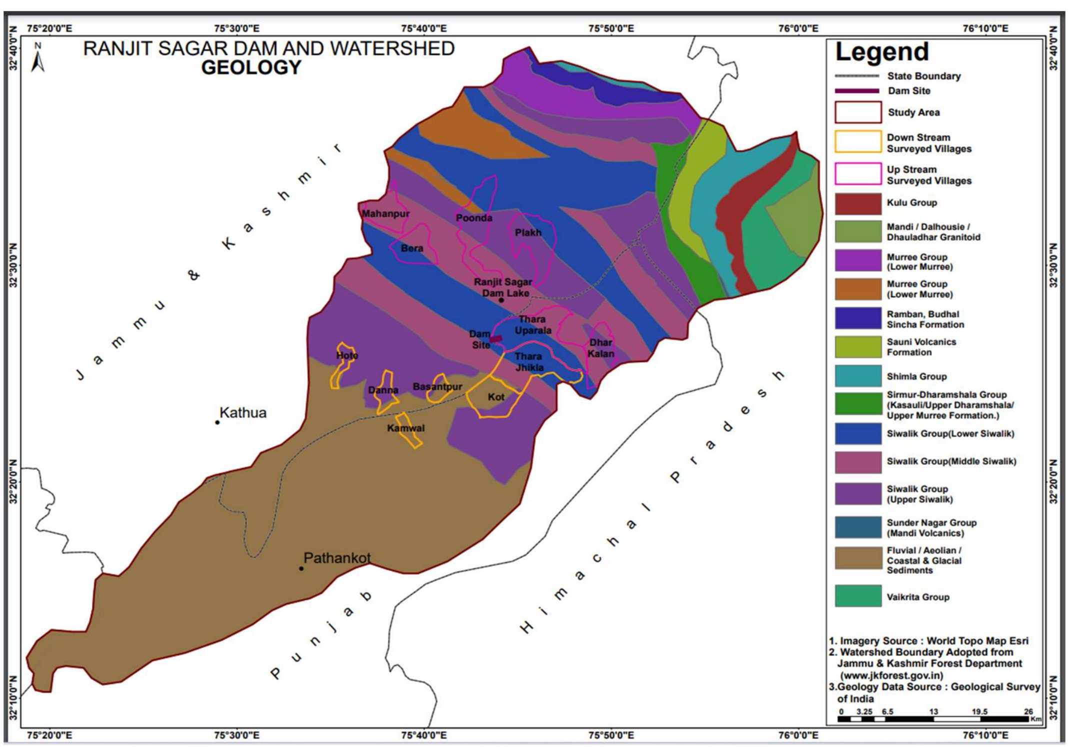


Table 2.1

Ranjit Sagar Dam Watershed: Area, Geological Age and Predominant Rocks of Siwalik Sub-Groups

Sub-Groups of Siwalik	Group wise Area (in Km^2) and (percentage)	Pre-dominant Rocks	Geological Age
Pre-Siwalik (Muree Formation)	73.29 (5.4)*	Sandstones, Yellowish Brown to Brown Mudstone	Late Miocene and older
Lower Siwalik	205.55 (15.10)	Mud stones, Siltstones, Fine to coarse sandstones	Middle Miocene to Late Miocene
Middle Siwalik	177.42 (13.04)	Thick layers of Sandstones with minor mudstones	Early Pliocene to Middle Pliocene
Upper Siwalik	225.85 (16.60)	Conglomerates, Sandstones and Mudstones	Late Pliocene to Middle Pleistocene
Post Siwalik (Alluvial fans and Piedmont Plain)	483.06 (35.50)	Deposits of Secondary Boulder Conglomerates, Flood Plains with gravel, sand, silt and clay	Late Pleistocene to Holocene

Source: Sharma & Choudhri, 2020; Nath & Nandy,2021; Singh,2018 *out of total watershed area i.e. 1360.57km^2

2.2 Classification of Soils found in Ranjit Sagar Dam Watershed

Soil is a valuable natural resource as biological, geochemical and hydrological cycles are controlled by it (Wang, 2024).Soil texture is a key physical characteristic of soil that significantly impacts farming practices (Barman et al.2018). It refers to the proportions of sand, silt, and clay in a soil sample. These proportions, in turn, influence other agricultural factors such as soil water content, plant development, and the choice of crops to grow (Barman&Choudhury,2019).It influences nutrient supply, soil erosion and thus determines fertility of soil (Kasaragod et al.2024). Sandy soil has a low capacity to retain water and contains less organic matter.

In contrast, silt soil has a higher water retention capacity than sandy soil (Bae et al.2004). Clay soil has a high- water retention capacity, greater plasticity, and more thickness, whereas sandy soils lack these characteristics. The water holding capacity of sandy loam is lower compared to loam and silty clay soils (Barman&Choudhury,2019). Map 2.4 shows the major soil classes on the basis of soil texture of different regions of Ranjit Sagar Dam watershed.

In the upstream region, main soil texture is loamy-lithic, coarse loamy, fine loamy and loamy-skeletal soil. Silt Loam soil, loamy skeletal, Coarse to fine loamy soil, Sandy fine loamy soil, Sandy loam soil, Coarse Loamy Calcareous soil and silt soil texture are found in the downstream region of watershed (Map 2.4). Table 2.2 & 2.3 delineate distinct features of soils found in upstream and downstream region of watershed respectively. The soils in upstream region mainly subject to severe erosion Plate (2.1) whereas downstream soils undergo slight erosion and are more fertile and suitable for agriculture as compared to their counterparts.

Thus, gaining insight into the soil characteristics of a watershed helps to better understand the processes that govern erosion, water flow and retention, pollutant runoff, and site productivity, among other factors (Schoonover & Crim, 2015) as soil erosion greatly affects dam performance by causing reservoir siltation, which decreases capacity and increases the risk of flooding (Djoukbala et al.2024).

Additionally, future studies should concentrate on the long-term effects of erosion control strategies and investigate innovative methods for predicting soil erosion in the context of changing climate conditions. These efforts will improve comprehension and management of soil erosion risks in the area.

Table 2.2

Ranjit Sagar Dam Watershed: Characteristics and Area of Soil Classes Found in Upstream Region

Soil Classes	Class wise Area (in Km^2) and (percentage)	Characteristics
Loamy Lithic Soils	142.04 (10.44)	Very shallow and excessively drained. Undergoes severe erosion, found on steep slopes of rock outcrops.
Coarse-Loamy Soils	285.28 (20.96)	Found on steep slopes, medium deep, excessively drained and severe erosion activity
Fine Loamy Soils	144.03 (10.59)	Found on Moderate slopes, having moderate erosion and are medium deep and well drained
Loamy Skeletal Soils	167.27 (12.30)	Found on gentle slopes, having moderate to severe erosion, deep and excessively drained to some extent
Silt Loam Soil	206.32 (15.16)	Smooth and soft, well drained, quite fertile, effective moisture holding capacity

Source: Author's work; Enviroliteracy Team, 2024; Directorate of Agriculture, Jammu (J&K)

Map 2.4

Ranjit Sagar Dam Watershed: Soil Classification

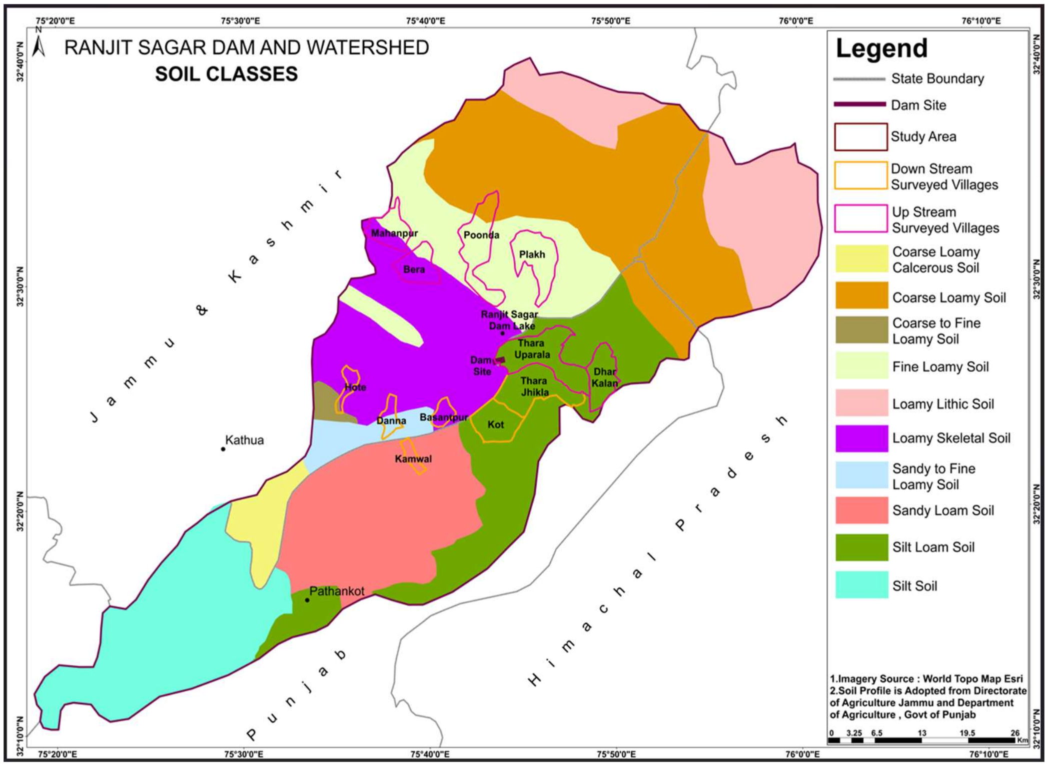


Plate 2.1

Source: Author's Work, 2024 This picture portrays severely eroded soils in upstream region of Ranjit Sagar Dam (near Thein Village)

Table 2.3

Ranjit Sagar Dam Watershed: Characteristics and Area of Soil Classes Found in Downstream Region

Soil Classes	Class wise Area (in Km^2) and (percentage)	Characteristics
Loamy Skeletal Soils	167.27 (12.30)	Found on gentle slopes, having moderate to severe erosion, deep and excessively drained to some extent, may not be much good for agriculture
Silt Loam Soil	206.32 (15.16)	Smooth and soft, well drained, quite fertile, effective moisture holding capacity
Coarse to Fine Loamy Soil	7.43 (0.55)	Formed on gentle slopes, deep and well drained, subjects to slight erosion
Sandy Fine Loamy Soil	26.37 (1.94)	Formed on gentle slopes with sandy surface, medium to deep, well drained, undergoes slight to moderate erosion
Coarse Loamy Calcareous Soil	31.43 (2.31)	Found on very gentle slopes, deep and moderately drained, undergoes moderate flooding and slight erosion.
Sandy Loam Soil	172.32 (12.66)	Sand particles are dominant, well drained, dry out quickly, less nutrient rich than other loams
Silt Soil	178.08 (13.09)	Smooth, formed due to river deposits, sometimes need drainage, potentially very fertile, sometimes undergoes erosion due to runoff

Source: Enviroliteracy Team, 2024; Directorate of Agriculture, Jammu (J&K); Finch et al.2014; Josa et al.2015

2.3 Land Use Land Cover Analysis and Vegetation of the Ranjit Sagar Dam watershed.

2.3.1 Land Use Land Cover in Ranjit Sagar Dam Watershed, 2023

Land cover describes the physical features of the Earth's surface, including the distribution of vegetation, water, soil, and other natural elements. Land use, on the other hand, pertains to how humans utilize the land for various purposes, such as agriculture, residential areas, and industrial activities (Bagwan & Gavali, 2021). Changes in land use and land cover have become a key focus in modern strategies for managing natural resources and tracking environmental shifts (Kaul & Sopan, 2012) as changes in land use and land cover directly affect land management practices, economic stability, and social processes in any region (Dwivedi et al.2005). Recognizing the patterns, factors, and consequences of land use changes is crucial for developing strategies that balance the various demands on land, protect ecological health, and promote sustainable development objectives (Turner et al., 2007). This section examines the Land Use Land Cover in Ranjit Sagar dam Watershed for the year 2023.

Map 2.5 shows the spatial expansion of LULC classes, and Table 2.4 specifies the total area covered by these classes in the study area. The description of each category is as follows:

Agricultural Land: Agriculture is the predominant land use within the Ranjit Sagar Dam Watershed area. This category represents extensive agricultural activities typically, characterized by the cultivation of Rabi crop (wheat) and Kharif Crop (Rice). In upstream region the agriculture is mainly rainfed. In downstream region, the fertile soils of alluvial plain of Ravi River and irrigation systems support large-scale agricultural production, making agriculture the most dominant land use, covering a substantial area of 589.76 square kilometres which is about 43.347% of total watershed area (Table 2.4). Agriculture in the study region can be driven by various factors such as more food production for growing population, communities relying on land cultivation for their livelihood as also explained in Figure 3.6 (a) & (b), availability of fertile soil and irrigation facilities, cultural and traditional practices that rely on land for subsistence.

Map 2.5

Ranjit Sagar Dam Watershed: Spatial Distribution of Land Use Land Cover Classes, 2023

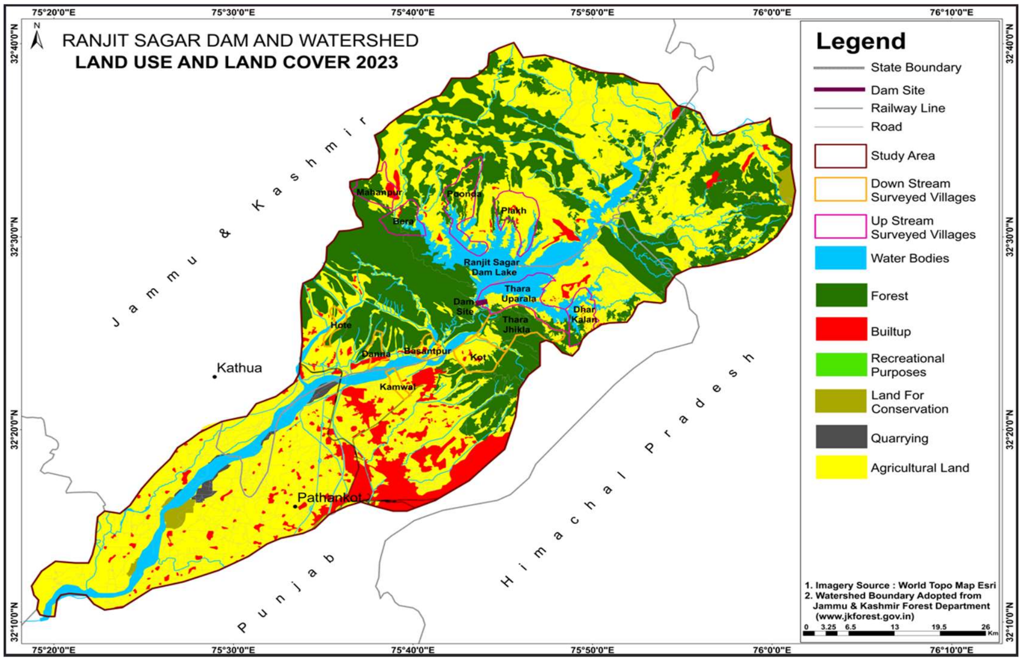


Table 2.4

Proportion of Land Use Land Cover Classes, 2023

CLASS	AREA (in Km^2)	Percentage of Total Area
Forest	388.81	28.577
Quarrying	12.62	0.928
Recreational Purposes	0.03	0.002
Land For Conservation	11.77	0.865
Water bodies	160.34	11.784
Built up	197.24	14.497
Agricultural Land	589.76	43.347
Total Area	**1360.57**	**100.000**

Forests: Forests comprise natural vegetative cover representing assemblage of patches of forests, woodlands, and shrublands that are vital in maintaining ecological balance and providing habitat for various species with in a region (Chazdon et al.2016). While less than agricultural land, this category within the Ranjit Sagar Dam watershed ecosystem covers about 388.81 square kilometres (28.577%) of total watershed area (Table 2.4). In Ranjit Sagar Dam Watershed, forests as a land cover can be influenced by a range of environmental and natural processes (topography, climate, soil types), ecosystem services and functions for various economic and social activities with in the dam watershed and conservation policy-related factors. Forests are critical for maintaining bio-diversity, air, water and soil quality for long-term sustainability of dam and its watershed (Francois et al.2024).

Built-up: The Built-up category denotes areas characterized by human infrastructure, including residential, commercial, and institutional structures (Schiavina et al.2022). Covering about 197.24 square kilometres which is 14.497% of the total watershed area (Table 2.4), these areas are relatively small in the context of Ranjit Sagar Dam Watershed but represent localized human settlements, roads, and associated infrastructure. As can be seen in the Map 2.5, the land under built-up covers more area particularly in the downstream region of Ranjit Sagar Dam watershed which may be typically influenced by economic, infrastructural and demographic factors due to rising demand for water resources, flood protection, land for housing, industry, recreation and commerce. This expansion of built-up in the watershed may come with various challenges such as land degradation, environmental pollution, water quality deterioration and loss of agricultural land, thus need to be properly planned and managed.

Water Bodies: Water Bodies represents the natural and man-made aquatic features such as rivers, lakes, reservoirs, streams, canals and ponds in Ranjit Sagar Dam Watershed (Map 2.5). Covering about 160.34 square kilometres which is 11.785 % of total watershed area (Table 2.4), the water bodies form an important part of Ravi River basin and are essential for agricultural and irrigational purposes, biodiversity and maintaining hydrological as well as ecological balance in the entire watershed. Creation and maintenance of water bodies as land use in Ranjit Sagar Dam Watershed may be shaped by both natural factors such as topography and climate as well as human factors such as Water resource management and construction of dams, reservoirs, canals for irrigation, flood protection and power production.

Quarrying: Quarrying refers to areas that are used for extracting sand and gravel generally located near riverbeds or mountains (Hoekstra,2015). As shown in the Map 2.5, Quarrying/Sand mining covers about 12.62 square kilometres (0.928%) of total watershed area (Table 2.4) and is the prominent anthropogenic activity (Plate 2.2) in downstream flood plain of Ravi River. As found by Tripathi et al. 2024 Quarrying in Ravi flood plain has led to river ponding (Plate 2.3) in river channel and flood plain which have been attributed to decreased water flow downstream post construction of Ranjit Sagar dam. The study found less imprints of anthropogenic activities in upper areas of flood plain downstream of Ranjit Sagar Dam reservoir as also shown in the Map 2.5. Further, the quarrying activity in downstream region of watershed is being done in proximity to the Kathlour Wildlife sanctuary (Map 2.5) which may lead to land degradation, habitat destruction and soil erosion.

Land for Conservation: This category with 11.77 square kilometres area represents 0.865% of total watershed area (Table 2.4) has relatively small coverage but these areas are very important for preventing further degradation of environment as land for conservation is specifically set aside for protecting natural ecosystems and biodiversity in a region (Buchadas et al.2022).These areas may include Ecological reserves, national Parks, Wildlife sanctuaries. As shown in the Map 2.4, less area of land is under conservation in Ranjit Sagar Dam Watershed. In the downstream region of watershed some area is conserved as Kathlour Kushlian Wildlife Sanctuary located in Pathankot District of Punjab state (Plate 2.4) and is home to numerous wildlife species such as porcupine, hog deer, barking deer, python, spotted owlet etc[6]. Also, in the upstream region of watershed, some area falls under Land conservation in Dalhousie Tehsil of H.P (Map 2.4). Areas under Land for conservation in Ranjit Sagar Dam Watershed are probably shaped by interlinked factors such as ecological importance, global climate

[6] https://pathankot.nic.in/tourist-place/kathlour-wildlife-sanctuary/

change mitigation goals, sustainable development goals, legal frameworks for bio-diversity protection and community involvement.

Plate 2.2

Source: Google ,2023 Aerial View of Quarrying activity in Ravi Floodplain (Satellite Imagery). Google Earth Pro. (https://earth.google.com/web/@32.27722585,75.46765891,598.04166566a,0d,35y,0.0003h,20.3103t,0r/data=CgRCAggBQgIIAEoNCPwEQAA)

Plate 2.3

Source: Google, 2022 Satellite Imagery of River Ponding in Ravi Floodplain due to Quarrying. Google Earth Pro.

(https://earth.google.com/web/@32.29847233,75.48864258,686.03962477a,0d,35y,0.016h,20.3343t,0r/data=CgRCAggBQgIIAEoNCPwEQAA)

Recreational Purposes: Land under Recreational Purposes covers the marginal area of 0.03 square kilometres which is only 0.002% of the total watershed area (Table 2.4). Land for Recreational purposes refer to land areas specifically designed for activities aimed at leisure, relaxation, sports, or entertainment. These areas can have significant value for public health and community well-being (Prajapati & Padhya, 2021). As shown in Map 2.4, land under recreational purpose fall in Dalhousie Tehsil (H.P) near Bakloh Cantonment (Plate 2.5). Land set aside for Recreational purposes in Ranjit Sagar watershed may be shaped by factors such as accessibility, community demands, cultural importance and economic opportunities. Proper management of these areas is important for safeguarding natural resources for future.

Plate 2.4

Source: Google,2023. Satellite Imagery of Kathlour Kushlian Wildlife Sanctuary. Google Earth Pro. (https://earth.google.com/web/@32.25867146,75.44982684,3776.28279382a,0d,35y,0.0003h,2.9682t,0.0001r/data=CgRCAggBQgIIAEoNCPwEQAA)

Plate 2.5

Source: Google,2024 Satellite Imagery of Land under Recreational Purposes(Triveni Play Ground, H.P). Google Earth pro

(https://earth.google.com/web/@32.46594107,75.92615992,32326.17741223a,34131.66954136d,35y,0h,0t,0r/data=CgRCAggBQgIIAEoNCPwEQAA)

2.3.2 Vegetation of Ranjit Sagar Dam Watershed

This section firstly examines the spatial distribution of different forest types in Ranjit Sagar dam Watershed followed by description of Riparian Vegetation and its distribution in the study region.

1. *Spatial Distribution of Forest types*

In any region, Vegetation consists of plants of same or diverse species. The vegetation is an outcome of soils, climate and anthropogenic activities of that region (Oxford University Press)[7]. Vegetation controls soil erosion, surface run off and sediments and thus plays an effective and significant role in preventing erosion of watersheds (Asgari et al.2021). Thus, in order to control the soil erosion and consequent sedimentation of dam's reservoir, plantation of diverse species of vegetation in the dams' watershed is essential (Butt et al.2010). Regarding the region around dam site about 90% area is under deep water and the rest is either shallow or marshy land. Few small islands are

[7] https://www.oxfordreference.com/display/10.1093/oi/authority.20110815111836789

also found where water level is low. The flora of the area is dominated by the aquatic conditions and is having different types of seasonal plants, grasses, shrubs (Sharma, 2023). Ranjit Sagar Dam exhibits an enormous diversity of habitats including garden, lake, agricultural land, grassland and bushes having a large number of trees, shrubs, herbs and climbers (Paunikar & Sharma, 2022). Table 2.5 describes the characteristics of different forest types found in Ranjit Sagar Dam watershed and geographical conditions required for each type. Map 2.6 Illustrates that Ban Oak Forest, Upper or Himalayan Chir Pine Forest, Lower or Siwalik Chir Pine Forest (Plate 2.6) are predominantly distributed in upstream region of dam watershed. Mostly, the downstream region of watershed is characterized by non-forest area. Himalayan Subtropical Scrub is exclusively found in northern parts of downstream region along with few patches of Lower Chir Pine Forest.

2. *Riparian Vegetation in Ranjit Sagar Dam Watershed*

Riparian vegetation includes all plant communities along river networks, regardless of their structure or origin. It plays a functional role in connecting fluvial systems with their surrounding environments (Dufour & Rodríguez-González, 2019).Riparian vegetation plays a crucial role in protecting and conserving soil and water while supporting river health. Its root system helps stabilize the soil, preventing erosion and maintaining the integrity of riverbanks (Khan et al.2022). As shown in Map 2.6 Riparian vegetation in Ranjit Sagar Dam Watershed includes Dry Deciduous Forests and Northern mixed Dry Deciduous Forests[8](Table 2.5) (Plates 2.7, 2.8, 2.9,) found along the banks of Ravi River and local streams in both upstream and downstream region. Also, Tripathi et al.2024 found that due to reduced water flow in floodplain of Ravi River downstream of Ranjit Sagar Dam, the riparian vegetation has increased growth with emergence of plant species adopted to less water conditions. The study found that Ranjit Sagar Dam has significantly impacted the downstream Ravi River flow system and highlighted the need of sustainable river management practices. But forest management practices influence various geophysical properties that impact raindrop-induced erosion within the watershed, ultimately affecting sediment

[8] https://forest.punjab.gov.in/en/forest/forest-types/

accumulation in the reservoir (Gunay et al.2024; Dutta, 2016;Gong et al.2022) which reduces their storage capacity (Patro et al., 2022) and negatively impacts overall water quality as also found in our study that downstream community has significantly strong perceptions (Table 5.20) regarding bad water quality downstream of Ranjit Sagar Dam.

Map 2.6

Ranjit Sagar Dam Watershed: Vegetation

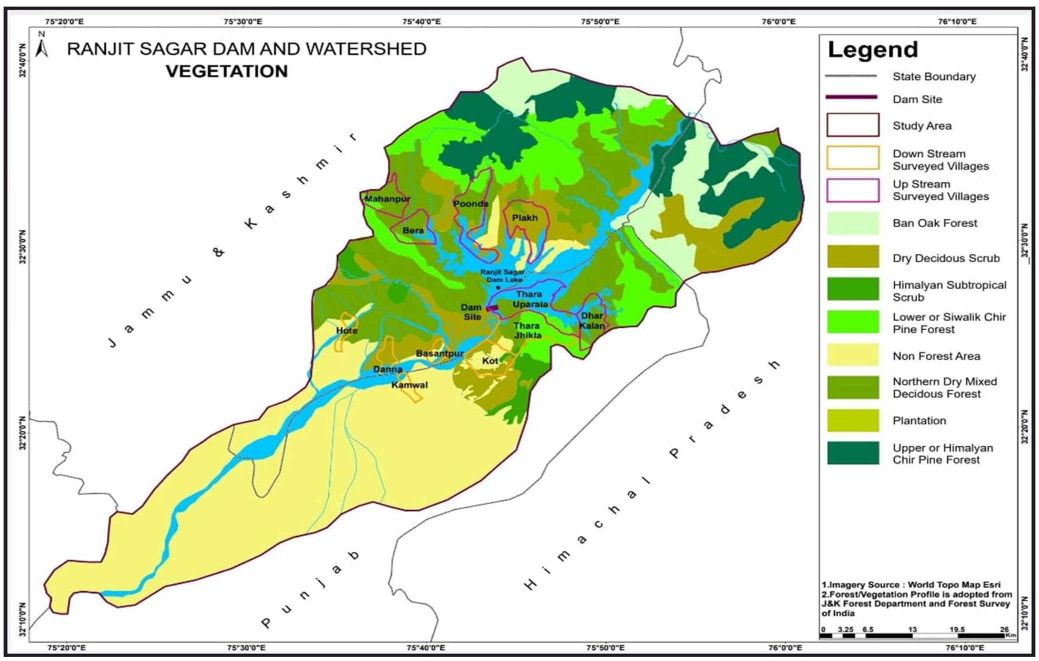


Plate 2.6

Source: Field Visit, 2023 Picture depicts the canopy of Lower Chir Pine Forests near Mahanpur

Plate 2.7

Source: Google, 2021 Aerial View of riparian vegetation along Ravi River Banks after rainy season. Google EarthPro (https://earth.google.com/web/@32.4320167,75.7353359,447.13111919a,3096.50038845d,35y,0.0007h,0t,0r/data=ChYqEAgBEgoyMDIxLTEwLTEzGAFCAggBQgIIAEoNCPwEQAA)

Thus, considering the community perceptions regarding bad quality of water downstream it is essential to conserve riparian vegetation which plays a crucial role in enhancing water quality by acting as a natural filter for pollutants (Dunea et al.2021). Without riparian vegetation surrounding the river, pollutants such as waste and heavy metals can freely enter the water (Kauffman et al.2022). Moreover, Cahyo et al.2024 found that riparian vegetation is essential for preserving water quality in springs within a watershed.

Plate 2.8

Source: Google, 2024 Satellite Imagery of riparian vegetation along the bank of Ravi River during dry season. Google Earth Pro. (https://earth.google.com/web/@32.4320167,75.7353359,3543.63134322a,0d,35y,0.0007h,0t,0r/data=CgRCAggBQgIIAEoNCPwEQAA)

Table 2.5

Ranjit Sagar Dam Watershed: Area and Characteristics of Forest Types

Type of Forests	Species with Local names	Geographical Conditions
Northern Dry Mixed Deciduous Forests	Gurjan, Baajhi, Amaltas, Fig (Peepal, Banyan), Phulai, Amla, Semal, Saj, Khair	Alluvial soil, 300-1200m altitude with 900-1200mm annual rainfall, 24-27^{0}C average temperature
Dry Deciduous Scrub	Thor, Gurjan, Dhai, Karonda, Mainphal, Khair,	Alluvial soil, 300-1200m altitude with 900-1150mm rainfall and 24-27^{0}C temperature
Ban Oak Forest	Banj, Aon, Lal Buransh, Tarajo	Soil with rich humus content, 1800-2300m altitude and 4-5^{0}C temperature
Himalayan Subtropical Scrub	Karonda, Mehndru, Tumra	Dry shallow soils, 1200-1800m altitude
Lower or Siwalik Chir Pine Forest	Chir, Harar, Khair, Kamala	Siwalik zone, below 1000m altitude and 15-20^{0}C temperature
Upper or Himalayan Chir Pine Forest	Chir, Khair, Sal, Banj	1200-1800m altitude, 900-2500mm rainfall and 15-20^{0}C temperature

Source: Author's work; Ashutosh et al. 2010

Plate 2.9

Source: Field work, 2024 View of lush green riparian vegetation along Ravi River banks during rainy season

Summary

This study about the physical resource base of the Ranjit Sagar Dam Watershed has highlighted several key factors that are critical for the dam's long-term sustainability.

- Topography of watershed is characterized by steep slopes in upstream region of dam and more gentles slope in the downstream regions of Ranjit Sagar dam. Steep slopes in places of higher reaches may have the potential for high rate of erosion which adds more sediments to the reservoir effecting its capacity and efficient operations.
- Physiography of the watershed has significant spatial variations as upstream region of dam watershed is marked by Siwalik hills having elevation up to 2500m in higher reaches whereas the downstream region is prominently covered with Piedmont plains having Kandi Belt in the northern parts and alluvial plains in its southern parts where elevation is as low as 250m from MSL. All these regions have different soil characteristics and varied agricultural conditions with Kandi belt has less agricultural productivity.
- Additionally, while the water resources in the watershed are generally abundant, seasonal fluctuations in water availability could pose challenges for the dam's operational efficiency during dry periods.
- Soils found in the watershed are mainly having loamy to silty texture. Soils of upstream region are exposed to severe erosion and are comparatively less fertile compared to the soils found in the downstream region of watershed. Soils that are highly exposed to erosion in a dam watershed can have far-reaching consequences for the dam's performance, it's capacity to control flood, increased risk to dam's structure due to load of sediments on walls, surrounding ecosystems involving degradation of land and reduced agricultural productivity, poor water quality in both upstream as well as downstream regions reduced water flow downstream and socio-economic impacts on population.
- Regarding riparian vegetation, the region is characterized by Dry Deciduous Scrub and Northern Mixed Dry Deciduous Forests along the river and stream banks. A healthy riparian vegetation is significant for controlling soil erosion of river banks and maintaining water quality.

- Geologically, the watershed is composed of young Siwalik hills with sandstone, mudstone and conglomerate as predominant rocks and may exposed to denudational processes. Tectonically also, the region is very active.
- The watershed is characterized by a mix of agricultural and forested land, which influences both water quality and sediment transport into the reservoir. Significant erosion was noted in the upper reaches of the watershed, which could lead to increased sedimentation and reduced reservoir capacity over time.

The findings suggest that managing land use practices, implementing erosion control measures, conserving riparian vegetation and monitoring water quality, regular inspection of dam region involving geo-technical studies will be vital to maintain the dam's effectiveness and ensuring the dam safety and overall sustainability of the watershed. It is recommended that future studies focus on the impacts of land management on sedimentation and further investigate strategies to optimize water storage during drought conditions, erosion control and soil conservation measures. Regular monitoring and adaptive management will be essential in safeguarding the physical resources that support the dam and surrounding ecosystems.

CHAPTER 3

SURVEY OVERVIEW AND GRAPHICAL ANALYSIS

In the progressively interrelated world, understanding the nexus of behaviors, attitudes and experiences of diverse communities is essential for executing better decision-making, productive policies and strategies. Same is the case with large dams, while these big water structures have profound socio-economic impacts in upstream region, these impacts also extend to downstream communities but the downstream impacts of large dams are often ignored during dam planning (Borogohain,2019). To comprehend the people's opinions regarding spatio-temporal impacts induced by Ranjit Sagar dam we collected the primary data to have valuable insights into diverse socio-economic impacts in both upstream and downstream region of Ranjit Sagar Dam. In this chapter an overview about General background of respondents and Graphical representation and interpretation of Survey responses is given. General information of Respondents helps us to have an understanding about demographics of surveyed individuals such as- Age, Occupation, Education and Income level which greatly influence the perceptions and attitudes of individuals about an issue and thus help us draw meaningful and applicable conclusions. For example, diverse perceptions between age groups and occupational backgrounds can give rise to varied opinions surrounding the topic and underscore the areas of general agreement and conflicts. Similarly, the visual representation of survey responses using line graphs, diverging bar graphs, pie-charts etc. serves as an effective and powerful tool for giving raw data a more comprehensive form of reading which we can use to identify the interrelated trends and patterns of numerical data. It helps us to illustrate the numerical information in such a simple manner which enhances the usability of findings for readers and stakeholders.

Therefore, in this chapter, firstly, an attempt has been made to analyse the general information of Respondents (both upstream and downstream region) in detail focussing on demographics (Gender, Age, Education, Occupation, and Income) that influence the survey results. Following this, the survey responses are presented graphically showcasing the data in different visual forms. In the end, hypotheses testing is done to assess the association of demographic variables and opinions of respondents regarding the proper implementation of resettlement policy in case of Ranjit Sagar Dam. Both primary and secondary data sources have been used to accomplish this chapter. Primary data has been collected through extensive field work in 528 households of twelve villages in the study area (Table 3.1).

Table 3.1

Ranjit Sagar Dam: Village Wise number of Sampled Households

S. No.	Village	Household	Sample Size* (10% of Total Households)
1	Hote	63	6
2	Kamwal	28	3
3	Bera	181	18
4	Danna	119	12
5	Basantpur	115	12
6	Dharkalan	266	27
7	Poonda	322	32
8	Thara Uprala	969	97
9	Thara Jhikla	667	67
10	Plakh	562	56
11	Kot	1051	105
12	Mahanpur	883	88
	Total	**5226**	**523****

Source: Census of India, District Census Handbook, Kathua, 2011; Census of India, District Census Handbook, Gurdaspur, 2011. ** Data collected for 528 samples. *Sampling design is explained in methodology section of chapter 1

After collecting data further steps like data coding, editing and tabulation and analysis has been done through Microsoft Excel. The results of the study have been presented through appropriate bar graphs, pie charts and maps. The chapter is grouped under following sections:

3.1 General Information of the Households

3.2 Average Income of Upstream and Downstream Respondents

3.3 Nature and Distribution of Data Collected

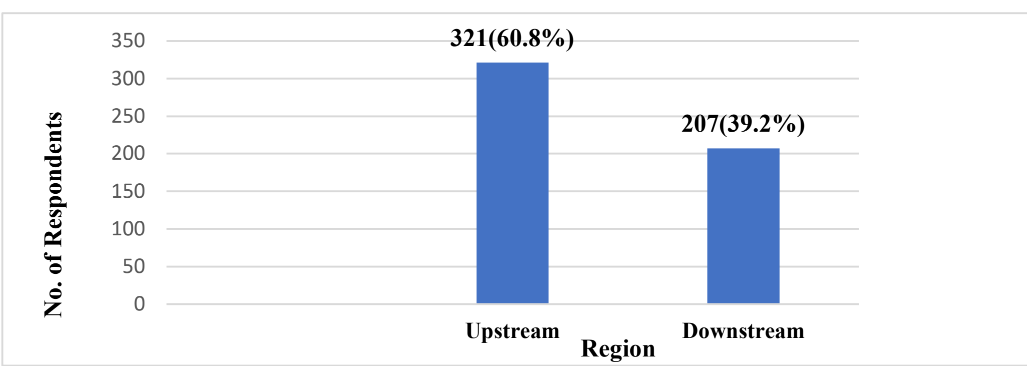
3.4 Perceptions of Upstream and Downstream Respondents Regarding Resettlement Policy of Ranjit Sagar Dam

3.1 General Information of the Households

During fieldwork or primary survey, general information about household is crucial for number of reasons. It provides essential demographic information about households; including their size, make up and location, which is crucial for the study. Researchers can better comprehend the context of a survey by learning general household information. This contains details about households' economic status, traditions and living arrangements, all of which might affect survey results. It enables researchers to contextualize survey results and make necessary corrections to data analysis and interpretation. It is possible for researchers to verify the precision and calibre of the data gathered during the survey using general household information. It aids in confirming the consistency and dependability of the household responses. During fieldwork for the present study, 528 households were surveyed. The gender distribution, age range, educational level, size of the household, the primary source of income, etc. have all been discussed in this section. It is evident from the study, that out of total respondents (528) to the survey, about 60.8% (321 respondents) are from Upstream and 39.2 % (207 respondents) are from Downstream (Figure 3.1).

Figure 3.1

Ranjit Sagar Dam: Number of Upstream and Downstream Respondents

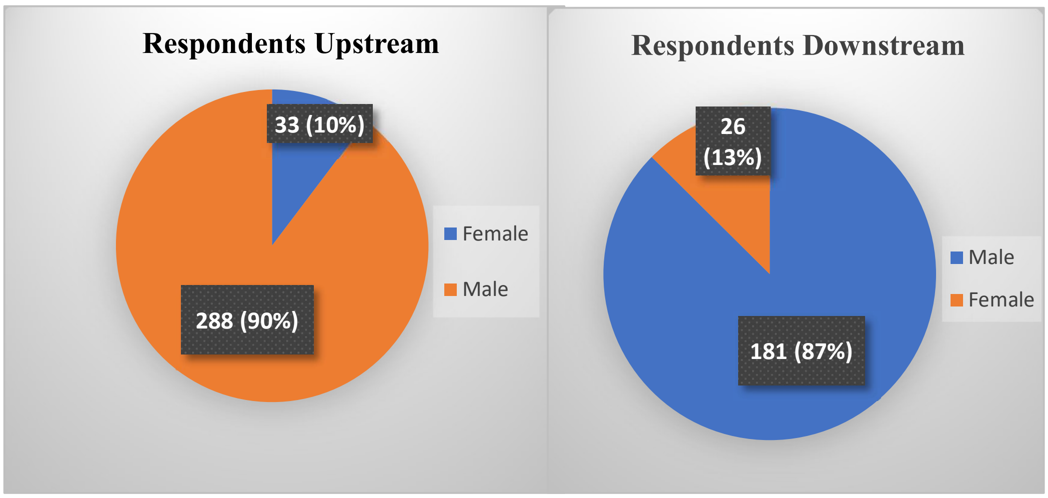


Source: Field Work, 2022-2024

During Primary Survey, respondents having gender (Male and Female) are covered. As shown in Figure 3.2, out of 321 Upstream Respondents, 288(90%) are Male and 33(10%) are Female. In Case of Downstream Respondents, out of 207, 181 (87%) are Male and 26 (13%) are Female.

Figure 3.2

Ranjit Sagar Dam: Gender Composition of Respondents



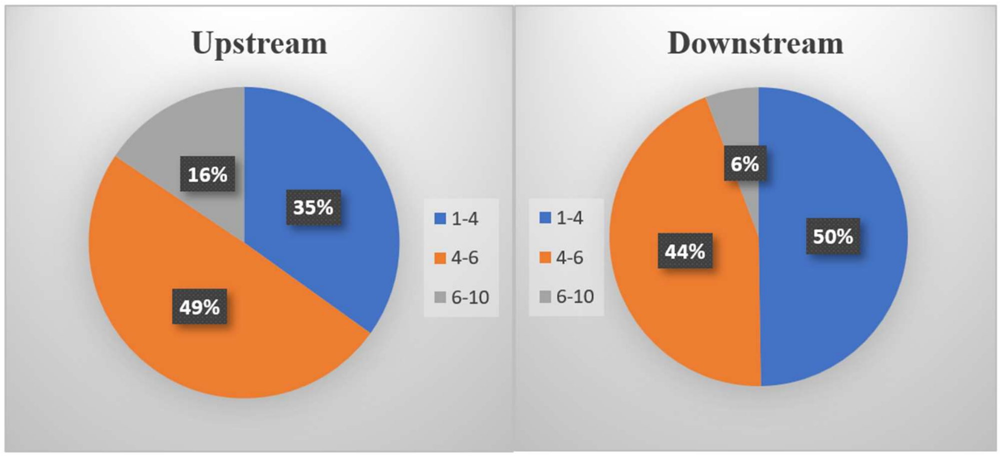
Source: Field Work, 2022-2024

The Figure 3.3 shows the household size on the basis of number of members. The results show that in upstream region 49% households have 4 to 6 members and 35% households have 1 to 4 members. On the contrary, 50% Downstream households have 1 to 4 members indicating the dominance of nuclear family system and 44% households have 4 to 6 members. Noteworthy, in both regions, households having members above 6, is less in number with 16% upstream households and only 6% downstream households which reflects the absence of large and multi-generational families.

During field survey, respondents of varied age group were covered. In case of Upstream Respondents, majority of them i.e. about 175 respondents (54.5%) are having age above 50 years followed by 112 (34.8%) respondents having age between 36-50 years. Out of total downstream respondents (207), about 97(46.8%) respondents having age above 50 years and 89 (42.9%) respondents are 36-50 years old (Figure 3.4). It is evident that large number of respondents from both regions are more than 50 years old and have witnessed the time pre and post construction of Ranjit Sagar Dam.

Figure 3.3

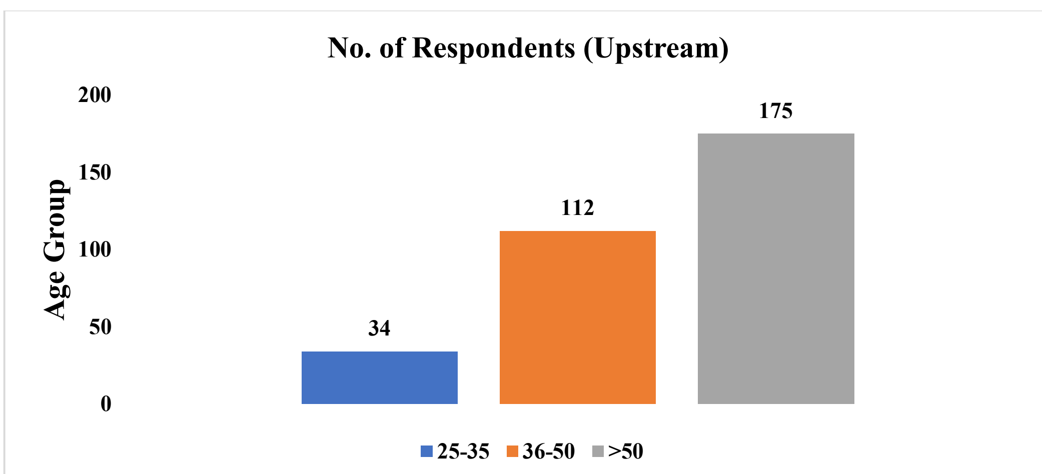
Ranjit Sagar Dam: Size of Households Surveyed



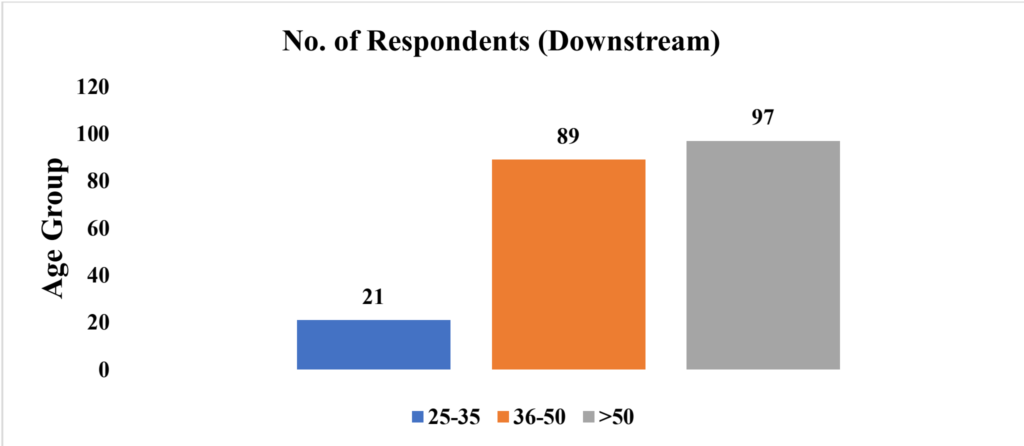
Source: Field Work, 2022-2024

Figure 3.4

Ranjit Sagar Dam: Age Group of Respondents



(a)

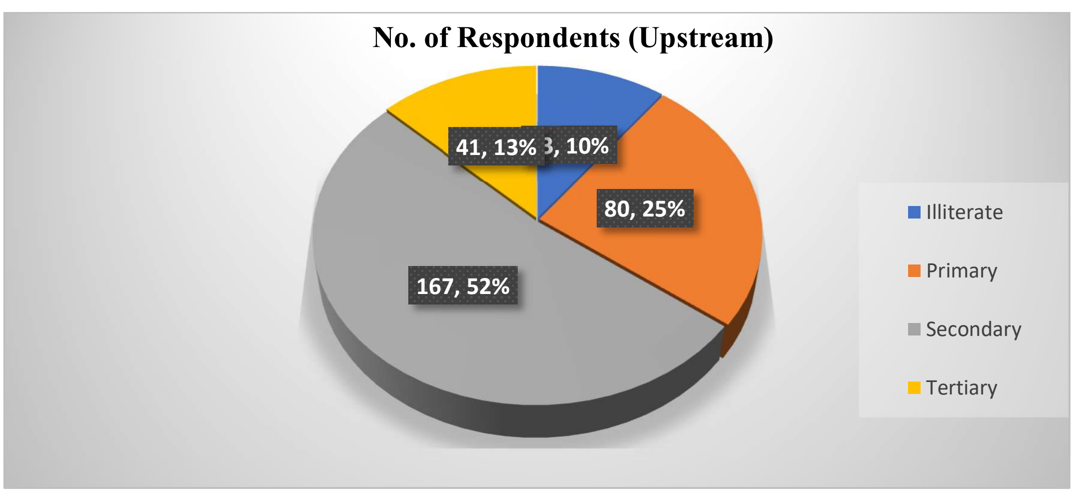


Source: Field work, 2022-2024 **(b)**

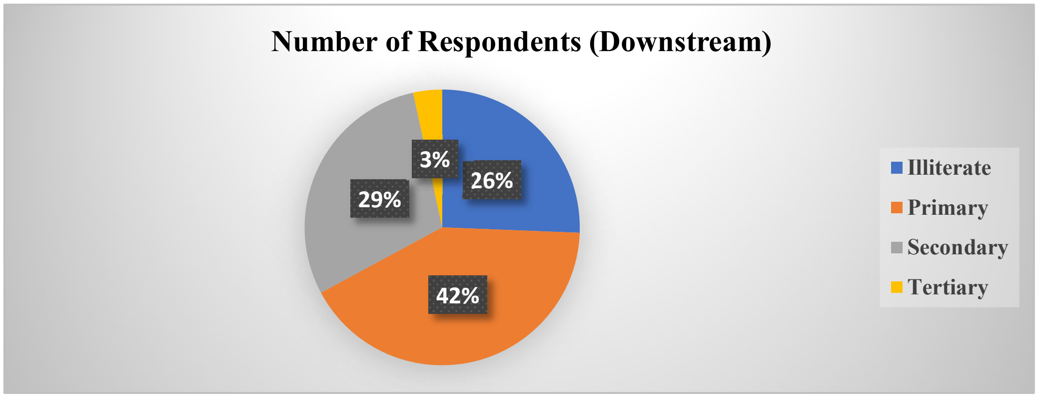
When educational status of respondents was examined, it becomes obvious that upstream and downstream regions have different educational status. Majority of the upstream respondents i.e. 52% (167) have secondary level of education. On the other side, majority of the downstream respondents i.e. 42% are having primary level of education. Additionally, for both regions, number of respondents having higher education is very less indicating low level of education among project affected people. In case of Downstream region, almost 1/4th of total respondents is illiterate which is more than the number of illiterate respondents upstream i.e. only (33)10% of total respondents (Figure 3.5, (a) & (b)).

Figure 3.5

Ranjit Sagar Dam: Education Status of Respondents



(a)



Source: Field work, 2022-2024 **(b)**

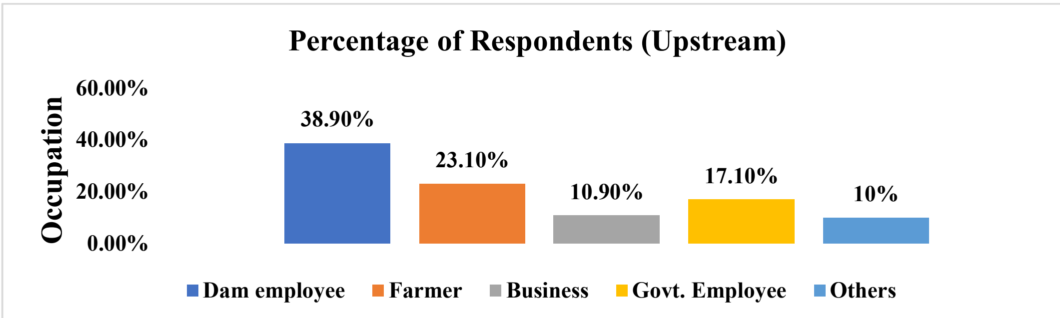
As the results shown in figure, 3.6 (a), most of the upstream respondents i.e. about 38.9% have got job due to Ranjit Sagar dam. Further, a significant number of respondents 23.10 % (are working as Farmer followed by people having Government job, where 17.10% respondents are employed and about 10.9% respondents are engaged in Business sector. Rest 10% respondents are engaged in “other” activities such as driving, tailoring etc.

As shown in figure, 3.6 (b), the result of occupational profile of respondents depicts that in downstream 33.3% of the respondents are engaged in primary sector of economy i.e. farming and about equal number of respondents (33.3%) have got employment due to Ranjit Sagar Dam. Less number of respondents are engaged in Government jobs and business which is about 10.10% & 12.60% respectively. Rest 10.60% downstream respondents earn their income through “other’’ activities such as driving, carpentry, tailoring etc.

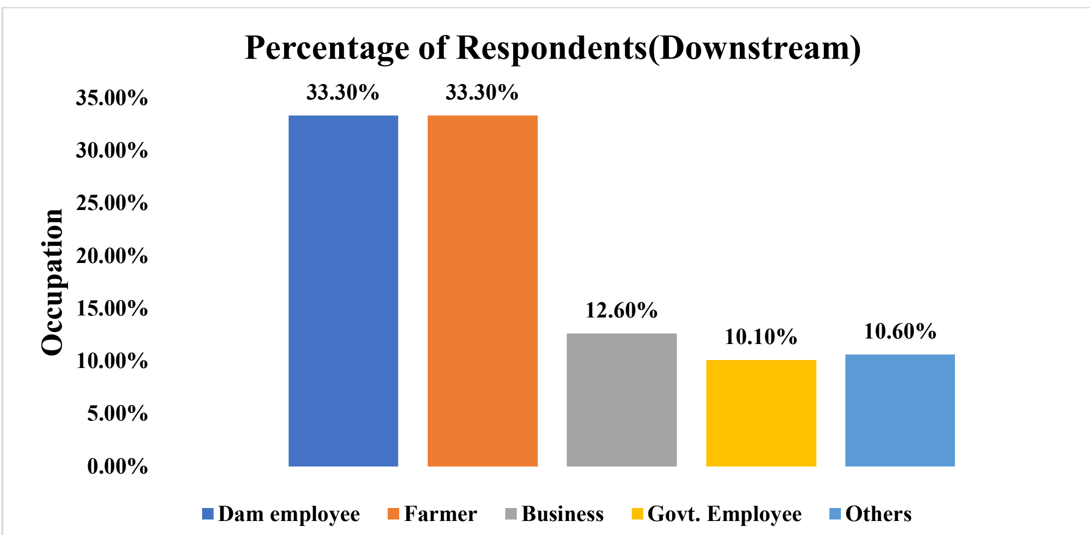
Noteworthy, 43.3% of total dam employee in upstream region are either illiterate or have got primary education. Similarly in downstream region, 75% of total Dam employee are either illiterate or having only Primary level education. It is significant to note that if Ranjit Sagar Dam had not been constructed, those illiterates or having primary education might not have got any employment opportunities due to lack of basic qualification required to have a government job. In other words, to an extent, the Ranjit Sagar Dam has a positive impact on livelihood for many. Overall, the results show a diverse occupation profile for both regions. In downstream regions majority of the respondents are either farmer or labourer where as in upstream region majority of the respondents are Dam employee followed by those engaged in farming or labour.

Figure 3.6

Ranjit Sagar Dam: Occupational Profile of Respondents



Source: Field work, 2022-2024 **(a)**



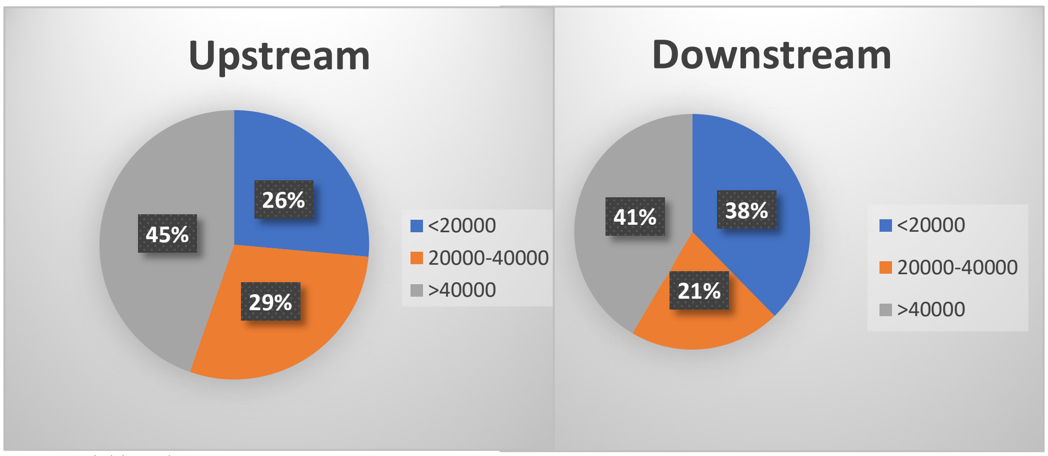
Source: Fieldwork, 2022-2024 **(b)**

3.2 Average Income of Upstream and Downstream Respondents

As shown in Figure 3.7, it is evident that in both upstream as well as downstream regions, majority of respondents have income more than Rs.40000 per month. In upstream region, 26% respondents are having monthly income less than Rs. 20000 and there are 38% downstream respondents having monthly income less than Rs. 20000. The results show that respondents in both regions are mostly employed in dam offices or in government job. Although there is significant number of Labourers/Farmers also who are earning less than Rs.20000 per month.

Figure 3.7

Ranjit Sagar Dam: Number of Respondents and Monthly Income



Source: Field work, 2022-2024

Further, to investigate the research question whether the Average income of upstream and downstream respondents is significantly different, hypothesis testing was incorporated.

To test the hypothesis, t-test was applied. A t-test compares the means of two groups or samples to determine if there is significant difference between them. The results of t-test are summarized in the Table 3.2.

The average monthly income for upstream and downstream respondents is Rs.33,349.53 and Rs. 30,676.32 respectively. Table 3.2, shows that p-value for independent samples test is less than .05 which means the average monthly income of both groups is significantly different. The result shows that average monthly income of both groups is significantly different. In other words, the average income of upstream respondents is significantly more than average income of downstream respondents. It indicates that as generally perceived that people living upstream of dams are at loss is not the case always as it seems that Ranjit Sagar Dam has positively impacted the income level of upstream respondents in comparison to the downstream counterparts. It underscores the unequal distribution of dam's benefits spatially, economic disparities and policy gaps for ensure equal growth opportunities. Proper corrective measures such as improved resource allocation and investment in disadvantaged region could help balancing interregional income differences.

Table 3.2

Ranjit Sagar Dam: Average Income of Upstream and Downstream Respondents

Group Statistics

	Villages	N	Mean	Std. Deviation	Std. Error Mean
Monthly Income	Upstream	321	33349.5327	14680.72955	819.39842
	Downstream	207	30676.3285	15580.25169	1082.90235

Independent Samples Test

		t-test for Equality of Means		
		T	d. f.	Sig. (2-tailed)
Monthly Income	Equal variances assumed	1.994	526	.047**

Source: SPSS version 21. ** significance level at 5%; d f=degree of freedom; Sig.(2-tailed) = P-value

3.3 Nature and Distribution of Collected Data

This section deals with presentation of primary data collected during Field work (Plates 3.1, 3.2, 3.3) in graphical form. To know about the patterns and characteristics of the data gathered during survey it is essential to present it in a systematic and arranged form. For effective analysis and decision -making, it is necessary to understand the nature of the data. As, Likert Scale has been used to ask questions to respondents, we have used Tables and Diverging Bar Graphs to show the arrangement or spread of the values of the gathered data. All the tabulation and analysis are done using MS-Excel. Number of tables and diverging bar graphs are used to present the responses under broad themes such as Impacts on Livelihood, Infrastructure and Community in both upstream and downstream regions during constructional as well as operational Phase of Ranjit Sagar dam. In the first section survey responses during constructional Phase in both upstream and downstream regions are discussed and in second section survey responses for operational Phase in both regions are explained.

Plate 3.1

(a) (b)

Source: Field Work, 2023 a) During Survey at Dhar Kalan; b) During Survey at Bera

Plate 3.2

(a) (b)

Source: Field Work, 2022 a) During Survey at Mahanpur; b) Basantpur Lift Irrigation Station

Plate 3.3

(a) (b)

Source: Field work, 2024 During survey at Kot

3.3.1 Survey Responses for Construction Phase (Upstream and Downstream)

3.3.1.1 Respondent's Views on Social Impacts/ Impacts on Community

Figure 3.8 (a) & (b), shows survey responses of people from upstream and downstream regions of Ranjit Sagar dam respectively. Respondent's views on various social impacts are assessed using Likert Scale (Table 3.3 and 3.4) and each impact is rated across five categories: Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree. Issues such as increased social conflicts, burden on resources, change in social system, increased mental health issues have been given special emphasis. As compared to downstream region, the data for upstream region indicates more widespread acknowledgement of the negative impacts associated with societal changes especially social conflicts, resource burden, mental health and social structures during constructional phase of dam.

Table 3.3

Number and Percentage of Survey Responses during Construction Phase (Upstream)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
Increased Mental Health Issues	3 (0.93)*	50 (15.6)	127 (39.56)	102 (31.78)	39 (12.15)	321 (100.00)
Change in Social System	1(0.31)	13 (4.04)	83 (25.85)	170 (52.96)	54 (16.82)	321 (100.00)
Burden on Resources	1(0.31)	31 (9.66)	129 (40.19)	127 (39.56)	33 (10.28)	321 (100.00)
Increased Social Conflicts	12 (3.74)	41 (12.77)	121 (37.70)	115 (35.82)	32 (9.97)	321 (100.00)

*Number of responses (percentage)

Figure 3.8 (a)

Ranjit Sagar Dam: Survey Responses for Impacts on Community (Upstream Region)

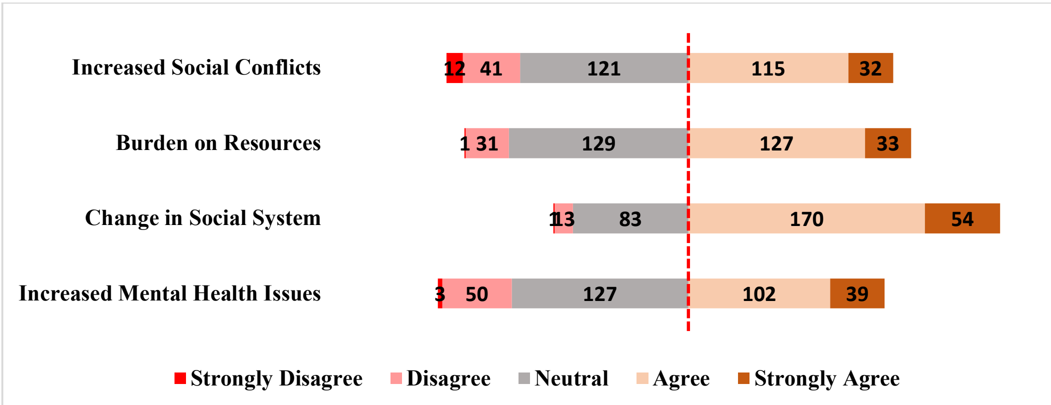


Table 3.4

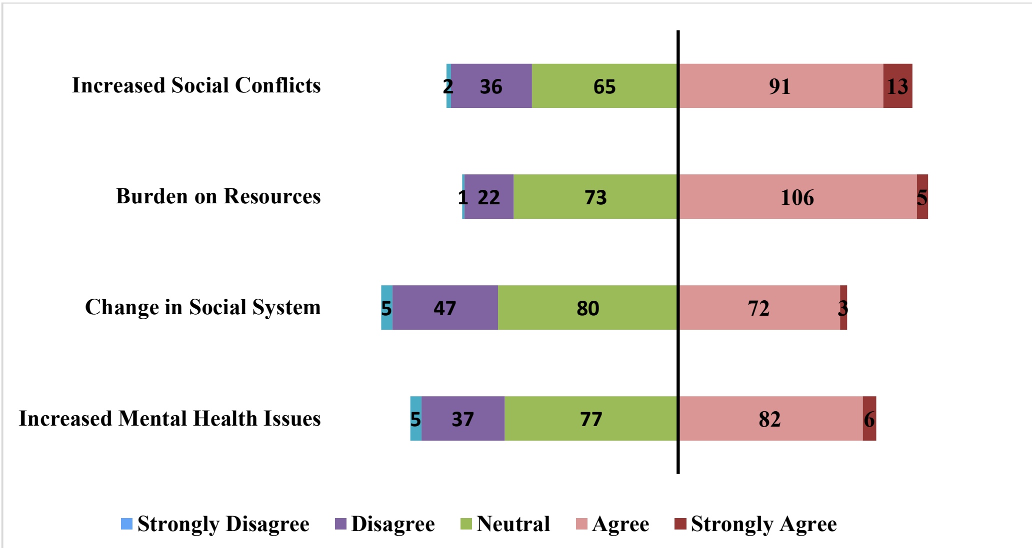
Ranjit Sagar Dam: Number and Percentage of Survey Responses for Impacts on Community (Downstream Region)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Increased Mental Health Issues	5 (2.42)*	37 (17.87)	77 (37.20)	82 (39.61)	6 (2.90)	207 (100.00)
Change in Social System	5 (2.42)	47 (22.70)	80 (38.64)	72 (34.78)	3 (1.45)	207 (100.00)
Burden on Resources	1 (0.48)	22 (10.63)	73 (35.27)	106 (51.21)	5 (2.42)	207 (100.00)
Increased Social Conflicts	2 (0.97)	36 (17.39)	65 (31.40)	91 (43.96)	13 (6.28)	207 (100.00)

*Number of responses (percentage)

Figure 3.8 (b)

Ranjit Sagar Dam: Survey Responses for Impacts on Community (Downstream Region)



Source: Field Work, 2022-2024

In case of downstream respondents, the most highlighted negative impact is burden on resources and associated conflict among community members. Although, a significant number of individuals agreed/strongly agreed for increased mental health issues and social change during construction of Ranjit Sagar Dam.

"During Construction of Ranjit Sagar Dam, many people working as laborers died due to one or other incident such as falling of rocks and heavy machine parts (Plate 3.4). Many of them also lost land due to submergence and for which did not receive timely compensation. As a result, there was burden on limited resources which was cause of conflict for families and increased mental health issues" -----Respondent from Upstream village Poonda.

"Due to Ranjit Sagar dam construction upstream communities got more profits. They got compensation and jobs. Their income level increased. But we got no compensation. We did not even get Ravi River water and other resources. We do not use the water of canal for our crops and other purposes. This canal (Plate 3.5) water is mainly for cities and towns located far away from this dam. Our agriculture is rainfed". -----------Respondent from Downstream village Danna.

Plate 3.4

Source: Collected from Office of Chief Executive Engineer, Ranjit Sagar Dam, Jugiyal   Picture depicts laborers working during construction of Ranjit Sagar Dam

Plate 3.5

Source: Field work, 2022   A View of Basantpur Irrigation Canal at village Danna

3.3.1.2 Respondent's Perspective for Economic Impacts/Impacts on Livelihood

Figure 3.9 (a) & (b) portrays the responses gathered for Economic Impacts or Impacts on Livelihood focusing mainly on change in cropping pattern, decreased agricultural production and consequent shift in their occupation from farming sector to labor, business, govt. sector and others. Table 3.5 & 3.6 and bar graphs for upstream as well as downstream region show varied perspectives regarding changed cropping pattern/decreased agricultural production and consequent employment opportunities. Respondents from both regions believed that due to construction of Ranjit Sagar Dam cropping pattern changed and agricultural production decreased but for consequent adoption of livelihood, respondents from both regions have varied attitudes. In case of adopting labor and business as livelihood after farming, more upstream respondents show agreement as compare to their downstream counterparts. A significant number of respondents from both regions have positive views on getting opportunities to get job as dam employee due to construction of Ranjit Sagar Dam.

Table 3.5

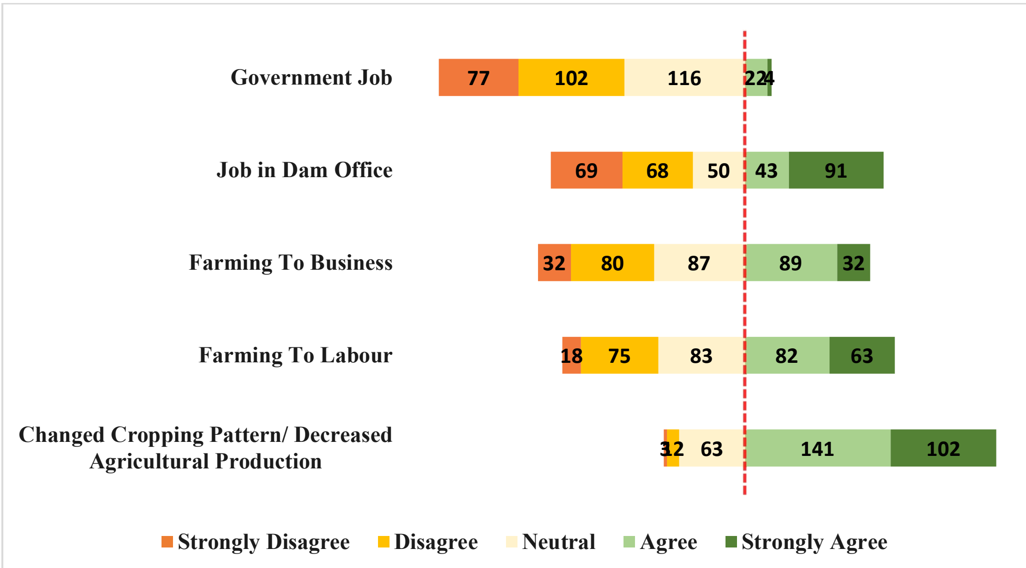
Ranjit Sagar Dam: Survey responses for Impact on Livelihood (Upstream)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
Changed Cropping Pattern/ Decreased Agricultural Production	3 (0.93)*	12 (3.74)	63 (19.63)	141 (43.93)	102 (31.78)	321 (100.00)
Farming To Labour	18 (5.61)	75 (23.36)	83 (25.86)	82 (25.55)	63 (19.63)	321 (100.00)
Farming To Business	32 (10.00)	80 (25.00)	87 (27.19)	89 (27.81)	32 (10.00)	320 (100.00)
Job in Dam Office	69 (21.50)	68 (21.18)	50 (15.58)	43 (13.40)	91 (28.35)	321 (100.00)
Government Job	77 (23.99)	102 (31.78)	116 (36.14)	22 (6.85)	4 (1.25)	321 (100.00)

*Number of responses (percentage)

Figure 3.9 (a)

Ranjit Sagar Dam: Survey responses for Impact on Livelihood (Upstream)



Similarly, in both regions the respondents believed that they didn't get much opportunities to earn livelihood by working as a government employee. This comparison exhibits the diverse trends and patterns of respondent's attitudes towards the Impact of Ranjit Sagar dam construction on their livelihood.

"Our family had 100% land loss due to reservoir inundation (Plate 3.6). Earlier we used to grow various Kharif and rabi crops but now we don't have land to grow anything. Some people had partial land loss, so they still grow some crops on their remaining land" --------Respondent from Upstream Village Bera.

"We don't use river water for irrigation purposes as the Ravi River has reduced flow downstream of dam during most of the months except in rainy season. We are not allowed to use Ravi River water as work is going on for construction of Shahpur Kandi barrage" --------respondent from Downstream village Basantpur.

Table 3.6

Ranjit Sagar Dam: Number and Percentage of Survey responses for Impact on Livelihood (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Changed Cropping Pattern/ Decreased Agricultural Production	4 (0.48)*	37 (17.62)	50 (23.81)	104 (49.52)	15 (7.14)	207 (100.00)
Farming To Labour	22 (10.63)	90 (43.48)	44 (21.26)	38 (18.36)	13 (6.28)	207 (100.00)
Farming To Business	22 (10.73)	138 (67.32)	34 (16.59)	11 (5.37)	0.00	205 (100.00)
Job in Dam Office	42 (20.49)	73 (35.61)	19 (9.27)	30 (14.63)	41 (20.00)	207 (100.00)
Government Job	31 (14.98)	110 (53.14)	52 (25.12)	14 (6.76)	0.00	207 (100.00)

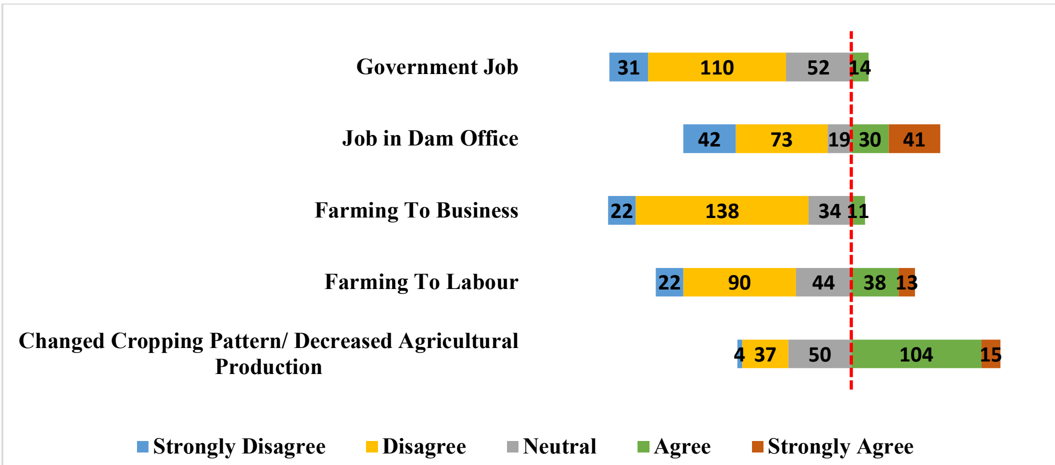
*Number of responses (percentage)

Plate 3.6

Source: Field work (18-09-2022)   Submerged Land near Village Bera

Figure 3.9 (b)

Ranjit Sagar Dam: Survey responses for Impact on Livelihood (Downstream)



Source: Field work, 2022-2024

Plate 3.7

Source: Field Work, 2024 A view of dried bed of Ravi River as it crosses village Basantpur

3.3.1.3 Respondent's Perspective for Impacts on Infrastructure

As figure 3.10 (a) & (b) and Table 3.7 &3.8 illustrates the survey response of individuals residing in upstream and downstream on infrastructural changes during constructional phase of Ranjit Sagar Dam, it is utterly understandable that respondents from both the regions have exactly contrasting opinions regarding the impacts on infrastructure such as loss of cultural monuments, buildings and roads. A large number of upstream respondents acknowledged that there was loss of cultural monuments (Plate 3.8), buildings and roads likely due to reservoir inundation due to construction of dam. Considering all this, it may be said that in upstream region respondents perceive that there was a negative impact of dam construction on infrastructure. On the contrary, lot of downstream respondents show their disagreement for any notable infrastructural losses due to construction of Ranjit Sagar Dam.

Table 3.7

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Upstream)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
Loss of Cultural Monuments	0 (0.00)*	10 (3.11)	54 (16.82)	180 (56.07)	77 (24.00)	321 (100.00)
Loss of Roads and Buildings	0 (0.00)	7 (2.18)	43 (13.40)	165 (51.40)	106 (33.02)	321 (100.00)

*Number of responses (percentage)

Figure 3.10 (a)

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Upstream)

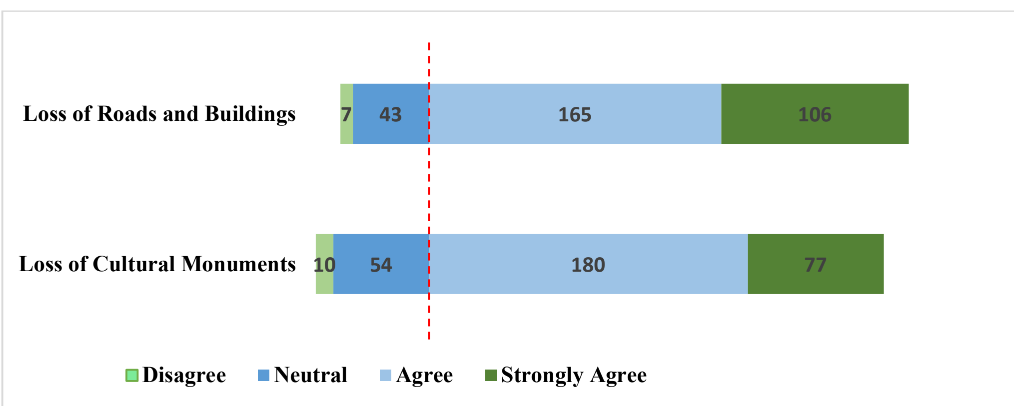


Table 3.8

Ranjit Sagar Dam: Number and Percentage of Survey Responses for Impact on Infrastructure (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Loss of Cultural Monuments	3 (1.45)*	57 (27.54)	131 (63.29)	14 (6.76)	2 (0.97)	207 (100.00)
Loss of Buildings and Roads	8 (3.86)	87 (42.03)	93 (44.93)	17 (8.21)	2 (0.97)	207 (100.00)

*Number of responses (percentage)

Figure 3.10 (b)

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Downstream)

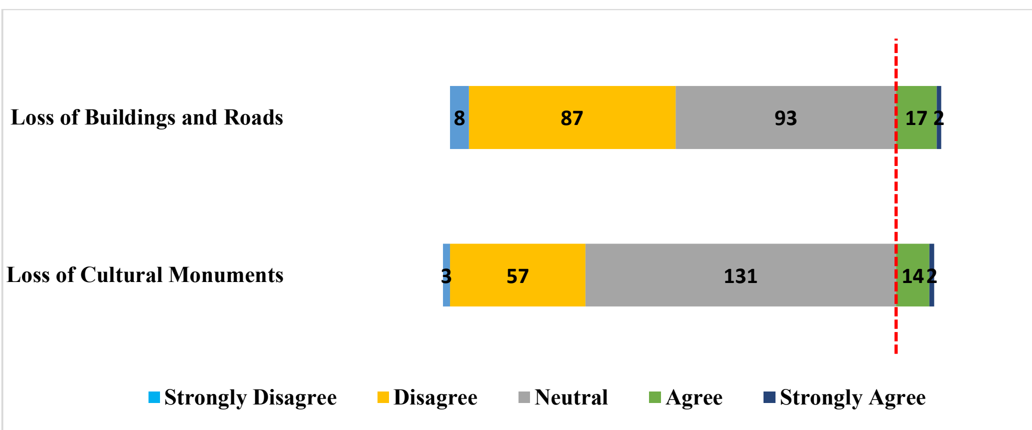


Plate 3.8

Source: Field work, 2022 Picture portrays a submerged temple due to Ranjit Sagar Dam reservoir inundation near Basholi Town (J&K)

3.3.2 Survey Responses During Operational Phase (Upstream and Downstream)

This section describes the survey responses of upstream and downstream respondents for Social Impacts/ Impacts on Community, Economic Impacts/ Impacts on livelihood and Impacts on Infrastructure during operational Phase of Ranjit Sagar Dam. As this section proceed, we will discuss the various similarities and dissimilarities of upstream and downstream survey responses.

3.3.2.1 Respondent's Perspective for Economic Impacts/Impacts on Livelihood

As we compare the responses depicted in Figure 3.11 (a) & (b), it is clear that respondents from both regions have diverse opinions particularly on business flourishment during operational phase of Ranjit Sagar dam. In case of Upstream region (Table 3.9), there are some positive responses regarding business flourishment and increased employment but there is significant disagreement on business flourishment and low level of agreement on increased employment in downstream region (Table 3.10). Overall, the upstream respondents have favorable opinion regarding increase in employment and flourishment in business but downstream responses are somewhat doubtful or having high level of disagreement. For increased income and reduced poverty both respondents have positive views but downstream respondents show some negative sentiments also with significant level of disagreement.

Table 3.9

Ranjit Sagar Dam: Survey Responses for Impact on Livelihood (Upstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Increase in Employment	60 (18.69)*	63 (19.63)	80 (24.92)	80 (24.92)	38 (11.84)	321 (100.00)
Business Flourished	30 (9.35)	100 (31.15)	88 (27.41)	70 (21.81)	33 (10.28)	321 (100.00)
Increase in Income and Reduced Poverty	39 (12.15)	81 (25.23)	87 (27.10)	83 (25.86)	31 (9.66)	321 (100.00)

*Number of responses (percentage)

Figure 3.11 (a)

Ranjit Sagar Dam: Survey Responses for Impact on Livelihood (Upstream)

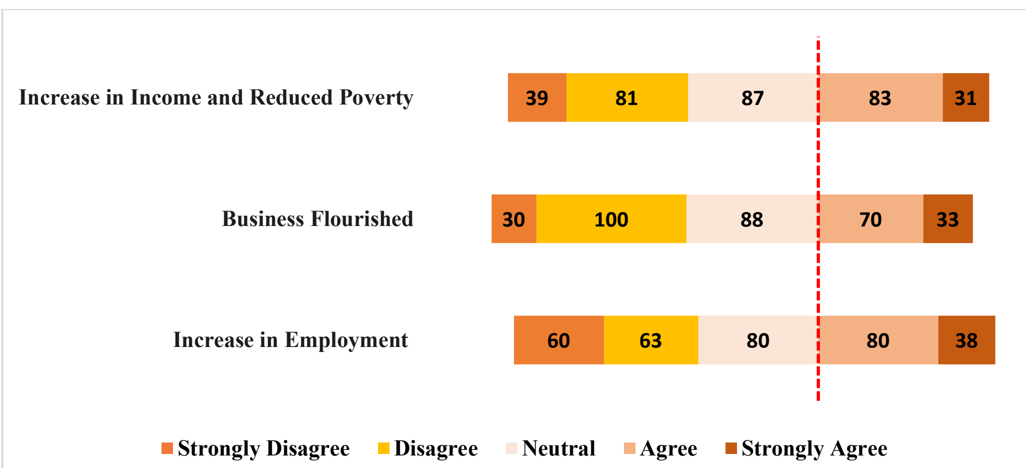


Table 3.10

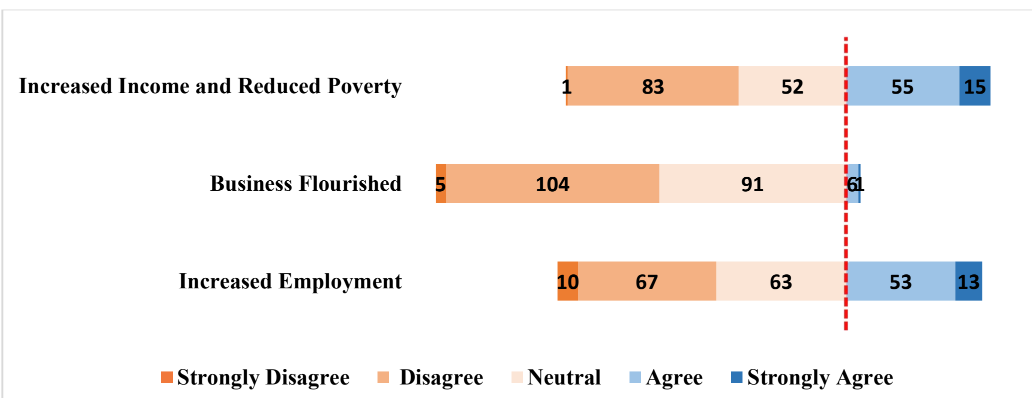
Ranjit Sagar Dam: Survey Responses for Impact on Livelihood (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Increased Employment	10 (4.85)*	0 (0.00)	63 (30.58)	53 (25.73)	13 (6.31)
Business Flourished	5 (2.42)	0 (0.00)	91 (43.96)	6 (2.90)	1 (0.48)
Increased Income and Reduced Poverty	(0.49)1	0 (0.00)	52 (25.24)	55 (26.70)	15 (7.28)

*Number of responses (percentage)

Figure 3.11 (b)

Ranjit Sagar Dam: Survey Responses for Impact on Livelihood (Downstream)



Source: Field work, 2022-2024

3.3.2.2 Respondent's Views on Social Impacts/ Impacts on Community

As presented in Figure 3.12 (a) & (b), the data depicts the responses for Impacts on Community specifically focusing on access to resources such as sand mining and fishing. There seems a widespread disagreement for access to resources among the respondents of both upstream and downstream regions (Table 3.11& 3.12). Majority of the upstream respondents have a significantly higher level of disagreement for access to resources, yet very few of them also had positive responses indicating that either these respondents have easy availability of these resources in their vicinity or they have a special access to use these resources. In contrast, the downstream respondents show an outright disagreement for any access to fishing and sand mining during operational phase of Ranjit Sagar Dam revealing that the operational phase of Ranjit Sagar Dam has negatively impacted the downstream community.

Table 3.11

Ranjit Sagar Dam: Survey Responses for Impact on Community (Upstream)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
Access to Sand mining	83 (25.9)*	132 (41.1)	61 (19.0)	39 (12.1)	6 (1.9)	321 (100.00)
Access to Fishing	64 (19.9)	137 (42.7)	48 (15.0)	56 (17.4)	16 (5.0)	321 (100.00)

*Number of responses (percentage)

Figure 3.12 (a)

Ranjit Sagar Dam: Survey Responses for Impact on Community (Upstream)

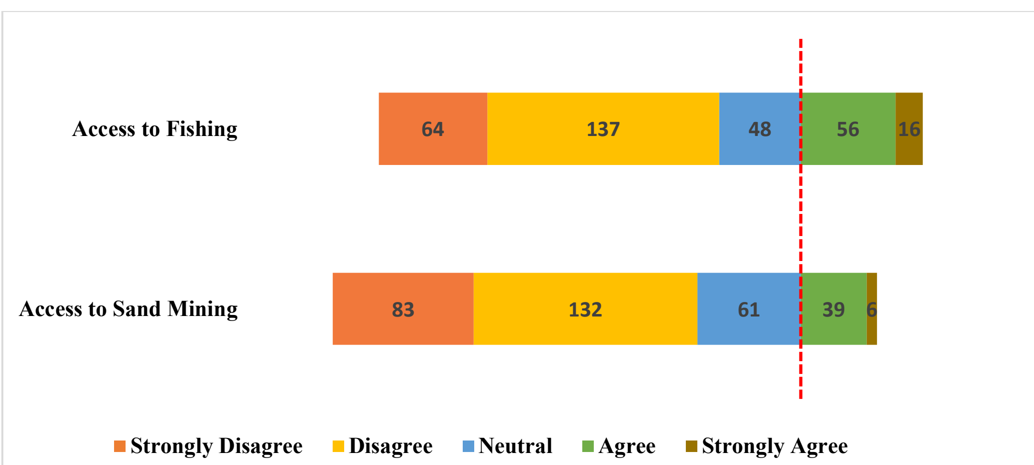


Table 3.12

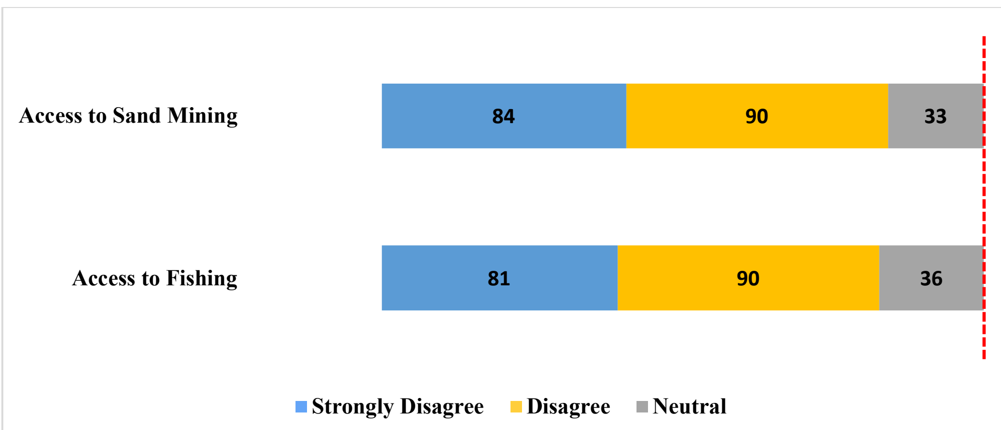
Ranjit Sagar Dam: Survey Responses for Impact on Community (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Access to Fishing	81 (39.13)*	90 (43.48)	36 (17.39)	0 (0.00)	0 (0.00)	207 (100.00)
Access to Sand Mining	84 (40.58)	90 (43.48)	33 (15.94)	0 (0.00)	0 (0.00)	207 (100.00)

*Number of responses (percentage)

Figure 3.12 (b)

Ranjit Sagar Dam: Survey Responses for Impact on Community (Downstream)



Source: Field work, 2022-2024

3.3.2.3 Respondent's Perspective for Impacts on Infrastructure

As we compare the responses depicted in Figure 3.13 (a) & (b), it is clear that respondents from both regions have diverse opinions particularly on Improved water facility during operational phase of Ranjit Sagar dam (Table 3.13 & 3.14). In case of upstream region, there are some positive responses regarding improved drinking water facility but there is outright disagreement on improved drinking water facility (Plate 3.9) and low level of agreement on opening of new school and colleges in downstream region. Overall, the downstream respondents have favorable opinion regarding improvement in road infrastructure but a significant number of respondents are somewhat doubtful or expressed disagreement also. On the contrary, upstream respondents have mixed opinions regarding improved roads (Plate 3.10). For free electricity and reduced power cuts both respondents have negative views but very few upstream respondents show some positive sentiments regarding electricity supply.

Table 3.13

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Upstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Improved Roads	65 (20.25)*	127 (39.56)	37 (11.53)	76 (23.68)	16 (4.98)	321 (100.00)
Improved Drinking Water Facility	82 (25.55)	122 (38.01)	53 (16.51)	52 (16.20)	12 (3.74)	321 (100.00)
New Schools and Colleges Opened	42 (13.21)	122 (38.36)	109 (34.28)	39 (12.26)	6 (1.89)	318 (100.00)
Free Electricity	197 (61.37)	89 (27.73)	32 (9.97)	2 (0.62)	1 (0.31)	321 (100.00)
Reduced Power Cuts	186 (57.94)	64 (19.94)	55 (17.13)	15 (4.67)	1 (0.31)	321 (100.00)

*Number of responses (percentage)

"The water quality is very bad here. It is not fit for drinking and even for bathing. We have got many health problems after using the water. There is a well in our village (Plate 3.9) but we have stopped using its water due to lowered level of water and sometimes animals like cats fall into it due to which water gets contaminated''-------Downstream Respondents from village Thara Jhikla.

Figure 3.13 (a)

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Upstream)

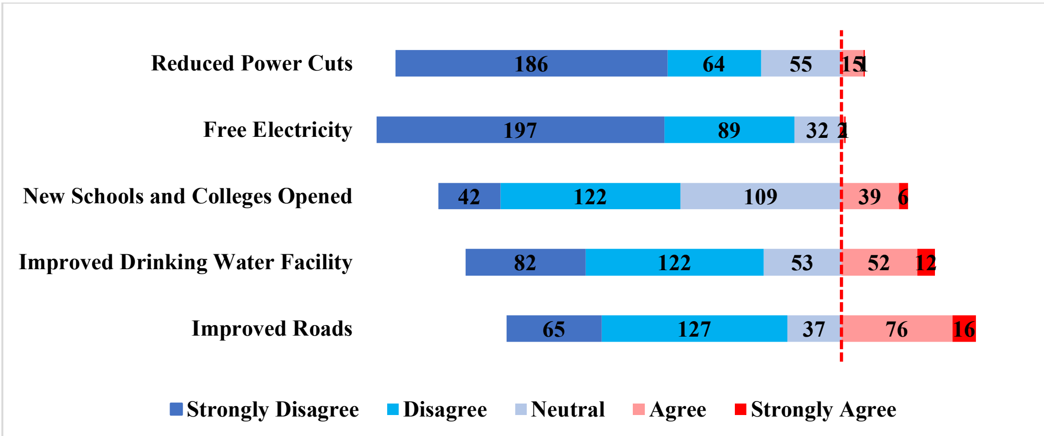


Table 3.14

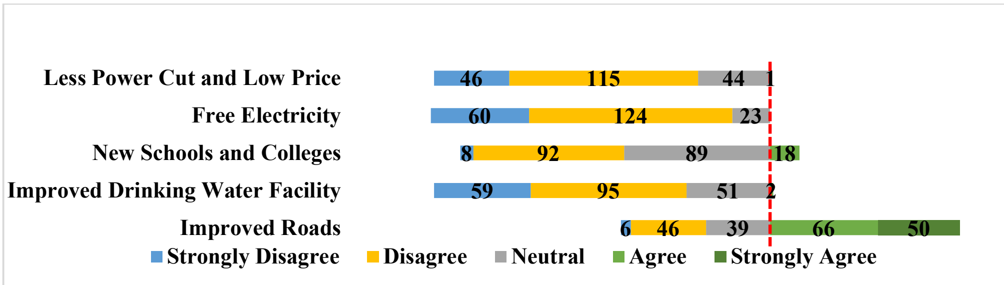
Ranjit Sagar Dam: Number and Percentage of Survey Responses for Impact on Infrastructure (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Improved Roads	6 (2.90)*	46 (22.22)	39 (18.84)	66 (31.88)	50 (24.15)	207 (100.00)
Improved Drinking Water Facility	59 (28.50)	95 (45.89)	51 (24.64)	2 (0.97)	0 (0.00)	207 (100.00)
New Schools and Colleges	8 (3.86)	92 (44.44)	89 (43.00)	18 (8.70)	0 (0.00)	207 (100.00)
Free Electricity	60 (28.99)	124 (59.90)	23 (11.11)	0 (0.00)	0 (0.00)	207 (100.00)
Less Power Cut and Low Price	46 (22.33)	115 (55.83)	44 (21.36)	1 (0.49)	0 (0.00)	206 (100.00)

*Number of responses (percentage)

Figure 3.13 (b)

Ranjit Sagar Dam: Survey Responses for Impact on Infrastructure (Downstream)



Source: Field Work, 2023

Plate 3.9

Source: Field work, 2023 Location of closed water well at Village Thara Jhikla, clicked during Field Visit

Plate 3.10

Source: Field work, 2022 An unmetalled road in the locality where Dam Oustees were resettled at Mahanpur (J&K)

3.4 Perceptions of Upstream and Downstream Respondents Regarding Resettlement Policy of Ranjit Sagar Dam

As land loss due to dam construction and consequent displacement of people is the major cause of socio-economic impacts induced by large dams. So, it is essential to have an insight about the implementation of Resettlement policy which determines the essence of induced socio-economic impacts. Thus, in this section, detailed analysis regarding perceptions of respondents on land loss and Implementation of Resettlement Policy by Ranjit Sagar Dam authorities is provided. In the end hypothesis testing is also done to assess whether the demographic variables have significant influence on opinions and attitudes of respondents regarding proper implementation of Resettlement policy

As figure 3.14 (a), depicts the results indicating that in upstream region more than 50% respondents have reported that they have land loss during construction of Ranjit Sagar Dam and 23% respondents reported partial land loss marked as “neutral” in the figure. Only 20% respondents said that they did not have any land loss due to Ranjit Sagar Dam Construction. Figure 3.14 (b), shows the reported land loss for downstream region. As depicted in the figure, only 39% of downstream respondents agreed for total land loss and 33% of them reported partial land loss marked in the figure as “neutral”. As per the downstream respondents, they lost their land during the operation period of Ranjit Sagar Dam, due to construction of Shahpur Kandi Barrage downstream. It can be summarized that respondents belonging to both the regions have lost their lands (Figure 3.14 (a) & 3.14 (b)) but the time factor plays a significant role here as in upstream region land was submerged during construction period where as in downstream region the land acquisition has taken place as a consequence of Shahpur Kandi Barrage under construction 15 km downstream which was a result of impacts induced during operational phase of Ranjit Sagar dam. Plates (3.11, 3.12, 3.13) presents scenario of Reservoir water level and submerged land during Monsoon, Summer and winter season in Upstream region. During Monsoons reservoir is full to its capacity while its lowest level is during winters in the year 2023. Plate 3.14 outlines the impact of under construction Shahpur Kandi barrage on River water downstream of Ranjit Sagar dam.

Plate 3.11

Source: Field Work, 2023 Submerged Land due to Ranjit Sagar Dam Reservoir (Upstream) during Monsoon season 2023

Plate 3.12

Source: Field Work, 2023 Submerged Land due to Ranjit Sagar Dam Reservoir (Upstream) during summer season 2023

Plate 3.13

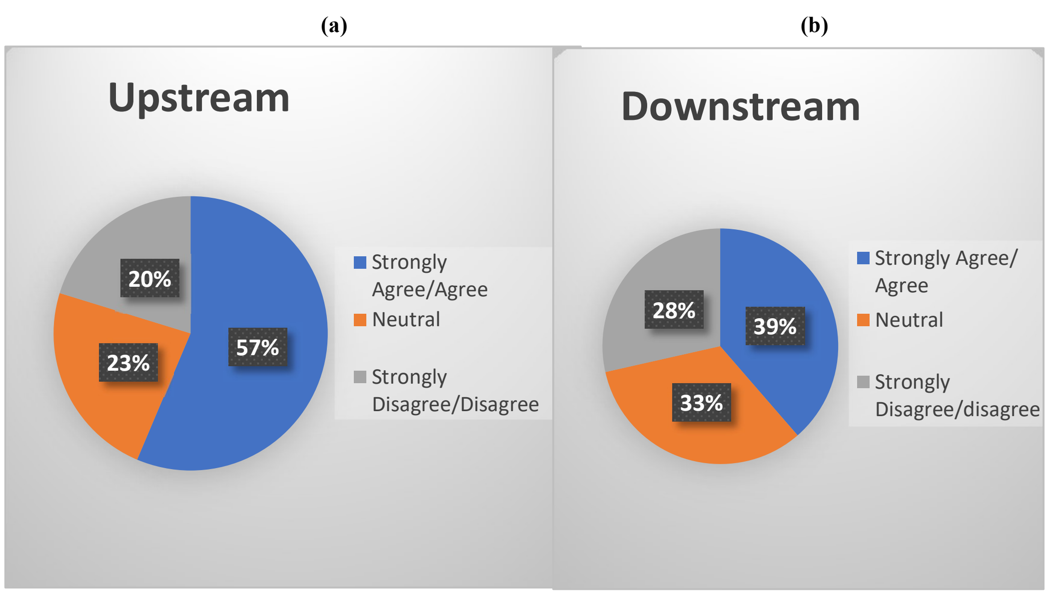
Source: Field Work, 2023 Exposed Land due to reduced water level of Ranjit Sagar Dam Reservoir (Upstream) during winter season 2023

Plate 3.14

Source: Field work, 2023 Diverted flow of Ravi River downstream of Ranjit Sagar Dam due to ongoing construction of Shahpur Kandi Barrage

Figure 3.14

Ranjit Sagar Dam: Percentage of Respondents who reported Land Loss



Source: Fieldwork, 2022-2024

Figure 3.15 shows the responses about Compensation for land loss in both upstream as well as downstream region. Figure 3.15 (a) shows that in upstream region, 53% (171) respondents seem dissatisfied for the compensation they got after the loss of their property and agreed that the compensation provided by government was not fair and timely. Also, 47% of total upstream respondents agreed that they got fair and timely compensation.

Figure 3.15 (b) is about the responses of downstream respondents. Out of total downstream respondents, 55% perceived that they got unfair and delayed compensation. On the other hand, about 45% respondents believed that the compensation was fair and timely.

Figure 3.15 (a)

Ranjit Sagar Dam: Responses regarding Resettlement Policy (Upstream)

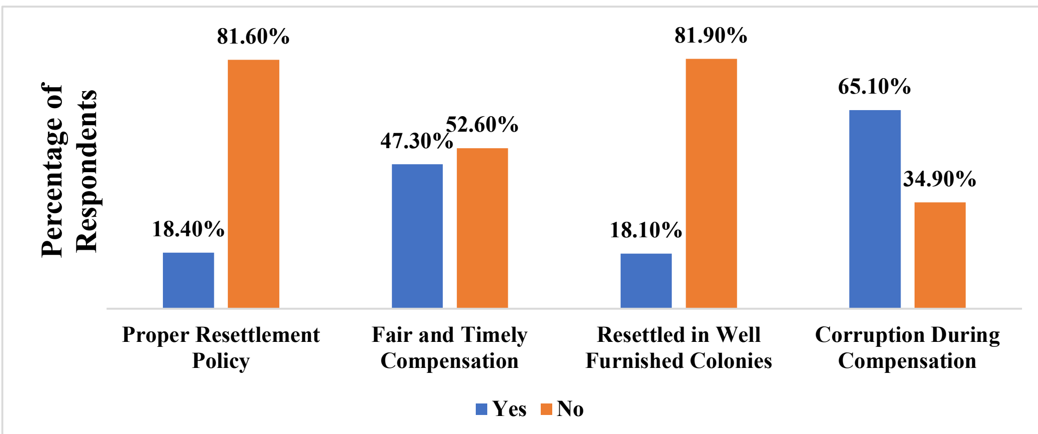
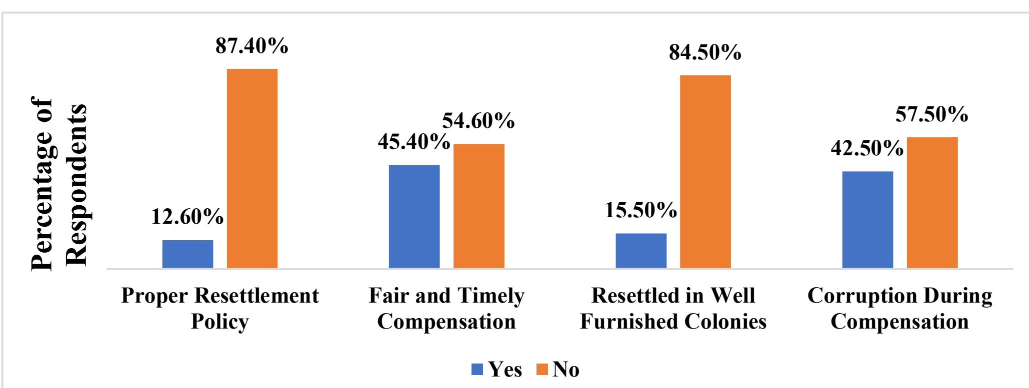


Figure 3.15 (b)

Ranjit Sagar Dam: Responses regarding Resettlement Policy (Downstream)



Source: Field work, 2022-2024

“Many dam employees have retired and they had left the colony. Now few employees and their families are living here. Initially, the construction of colony increased profit for shopkeepers as there were many people living in the colony. But now we have less customers, so business is at loss. Moreover, vacant apartments (Plate 3.15) have become a safe haven for drug peddlers and related crimes.” ----------Respondent of Upstream Village Thara Uparla.

Plate 3.15

Source: Field work, 10-03-2024 at Thara Uparala (Upstream region)

Colony built about 30 years ago (approximately) for dam employees

From Figure 3.15 (a) & (b), it is possible to analyze relationship between demographical variables (Occupation, Age, Education) and perceptions regarding Resettlement Policy.

To find out this relationship, the Chi-Square Test have been used, and the results are as follows:

Observation: Table 3.15, presents responses regarding Proper implementation of Resettlement policy by dam authorities based on different occupations. Majority of the respondents 262 (81.6%) among all the occupations disagree with the proper implementation of resettlement policy and 59 (18.4%) acknowledged that resettlement policy was properly implemented. To assess the association between occupation and perceptions regarding implementation of policy, Chi-square test was applied. The analysis shows that for 4 d. f. (degree of freedom) and p-value (.000) the Chi-square value is 30.737 which is significant at 1% level indicating a statistically significant relationship between occupation and attitude on implementation of Resettlement Policy. There is a notable diverse perspective as 12.1 % of the 125 Dam employee perceive that resettlement policy was properly implemented. Majority of other occupations such as farmers, business owners, govt. employees show disapproval for the policy. Thus, respondents' occupation remarkably influences their attitude towards resettlement policy. It may be due to varying level of impacts on different groups.

Table 3.15

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Perceptions Regarding Resettlement Policy

	Occupation	Proper Resettlement Policy by Dam Authorities			
		Yes	No	Total	Chi-Square
Occupation	Dam Employee	39(12.1%)	86(26.8%)	125(38.9%)	30.737***
	Farmer	5(1.6%)	69(21.5%)	74(23.1%)	
	Business	7(2.2%)	28(8.7%)	35(10.9%)	
	Government Job	1(0.3%)	54(16.8%)	55(17.1%)	
	Others	7(2.2%)	25(7.8%)	32(10.0%)	
	Total	59(18.4%)	262 (81.6%)	321(100%)	

() represents percentage and *** represents significance level at 1%

Observation: Table 3.16, details the perception regarding prevalence of corruption during compensation based on various occupation of upstream respondents. Dam Employees and Farmers report the greater incidence of perceived corruption during compensation. Respondents from business background have low level of perceived corruption and govt. employees have mixed views. In totality, 209(65.1%) people perceived corruption during compensation and 112(34.9%) believed that corruption was not prevalent during compensation. To evaluate the association between occupation and perceived corruption during compensation, Chi-square is used. As the results show, for 4 d. f. (degree of freedom) and p-value (.000), the value of Chi-square is 21.081 which is significant at 1% level. Thus, hypothesis stands validated indicating that opinions regarding corruption during compensation are significantly influenced by occupation.

Table 3.16

Ranjit Sagar Dam and Upstream Region: Association Between Occupation and Perceptions Regarding Resettlement Policy

		Corruption During Compensation			
Occupation		Yes	No	Total	Chi-Square
Occupation	Dam Employee	88(27.4)	37(11.5)	125(38.9)	21.081***
	Farmer	55(17.1)	19(5.9)	74(23.1)	
	Business	12(3.7)	23(7.2)	35(10.9)	
	Government Job	37(11.50)	18(5.6)	55(17.1)	
	Others	17(5.3)	15(4.7)	32(10.0)	
	Total	209(65.1)	112(34.9)	321(100)	

() represents percentage and *** significance level at 1%

There exists no significant association between Age, Education and Perceptions regarding Resettlement Policy for Upstream and Downstream region.

Summary

An overarching analysis of respondent's general information, visual representation of gathered data and hypotheses testing regarding perceptions on Implementation of Resettlement policy has been provided in this chapter. Following conclusions can be drawn from above analysis:

- Education Level: There are notable differences in education level of respondents from both the regions. The downstream region has higher level of illiteracy with 25% of respondents are illiterate compared to only 10% upstream respondents. A majority of upstream respondents, accounting for 52% (167 individuals), have achieved a secondary level of education. In contrast, the predominant educational attainment among downstream respondents is primary level, comprising 42% of that group. It highlights that upstream respondents may have access to better opportunities and educational facilities thus necessitating the focused educational interventions to improve literacy and education opportunities.
- Occupation: While we compare the employment status vis- a -vis upstream and downstream, out of the total respondents 38.9% are employed in Dam in case of upstream as compared to downstream where only 33.3% are only employed in Dam. Also, as far as farming is concerned only 23.1% are into this profession in upstream area as compared to 33.3% respondents downstream which indicates farming is basic profession in downstream. Further, in the government sector again 17.1% of the respondents from upstream are in the government job as compared to 10.1% in downstream. With such a pattern of employment and other opportunities, it indicates that people at upstream have more opportunities in Dam and Government service and people at downstream are more dependent on Farming.
- Income: There is significant difference in average monthly income of both upstream and downstream region. Average Income of Upstream Respondent is Rs. 33349.53 per month which is notably exceeds the average income (Rs.30,676.5) of downstream respondents. The analysis reveals the economic and social disparities between the two regions. It reflects that upstream

respondents may have better lifestyle choices, employment opportunities, access to resources, education and healthcare facilities which affects the socio-economic dynamics. These existing socio-economic inequalities underscores the need for further research and targeted interventions to give way for inclusive growth and improved livelihood of all the individuals in both the regions.

- From the graphical representation of survey responses during constructional phase of Ranjit Sagar dam, it is depicted that in upstream region, impact on infrastructure and social impacts are mostly perceived as negative whereas burden on resources is reported as adverse social impact by downstream region. Regarding economic impacts, respondents from both the regions consider that construction of Ranjit Sagar dam has negatively impacted agricultural production and getting a job due to employment is reported as positive impact of dam construction.
- The analysis of Survey Responses illustrates that during operational phase of Ranjit Sagar dam, Increased employment, business flourishment, Increased Income and Reduced poverty are perceived as positive economic impacts by upstream respondents whereas most of the downstream respondents have negative views regarding these components except Increased Income and reduced poverty. Further, bad quality of water is perceived as the most prominent negative infrastructural impacts by downstream respondents as compared to views of upstream respondents. There is widespread agreement among downstream individuals that they view Improvement in Road infrastructure as a positive impact. On the other had upstream respondents have mixed opinion regarding infrastructural Impacts. Further, in downstream region, lessened access to Ravi River resources such as sand and fishing is considered as the distinguished adverse Impact on community. In case of upstream region, few respondents reported access to sand mining and fishing. In general, Ranjit Sagar dam is perceived to be cause of more adverse socio-economic impacts in upstream region during constructional phase whereas it is viewed to have produced more adverse impacts in downstream region during operational phase.
- Perceptions on Resettlement Policy: It is found that individual’s opinion regarding implementation of Resettlement Policy is significantly influenced by

Occupation in upstream region. Almost all occupational groups show disapproval regarding proper implementation of Resettlement Policy which specifies that different groups are not satisfied the way the resettlement policy was implemented may be due to perceived inadequate compensation and its effects on socio-economics dynamics of the region due to dam construction of dam. However, a specific segment of Dam employees i.e. about 12.1% of them either acknowledge that Resettlement policy was properly implemented by dam authorities indicating that either these people didn't face the adverse impacts of dam construction or the resettlement policy could mitigate adverse impacts for few people only. It highlights the need of key policy implications such as regular monitoring of resettlement policy; to address the concerns of different occupational groups, future projects should be based on comprehensive evaluation of potential socio-economic impacts, more inclusive approach and alternate compensation strategies.

On the whole, synthesizing of respondent information and visual data representation set out a vital foundation for the further analysis and discussion chapters providing a preliminary work for a more refined research and investigation of the findings and their inferences which will guide the stakeholders for enhanced monitoring and improving the decision-making. Following chapters deal with empirical testing of socio-economic impacts as reported by respondents.

CHAPTER 4

SOCIO-ECONOMIC IMPACTS INDUCED BY RANJIT SAGAR DAM IN UPSTREAM REGION

This chapter presents a comprehensive statistical investigation into the opinions and perceptions of multiple stakeholders regarding the socio-economic impacts associated with Ranjit Sagar dam construction in the upstream region, focusing on both the construction and operational phases. The analysis categorizes the socio-economic impacts into broad themes—specifically, Impacts on Livelihood, Infrastructure, and Community—structured according to Matrix Framework (Kirchherr & Charles 2016). Each of these overarching themes encompasses various sub-components that detail the specific effects experienced by different groups.

To further understand the dynamics at play, the chapter also explores the relationship between various demographic variables, including Occupation, Age, and Education, and the socio-economic components identified. This is achieved through hypothesis testing utilizing the Chi-Square Test, a robust statistical method that allows for the examination of associations between categorical variables.

The organization of the chapter includes several main sections and corresponding sub-sections, each designed to provide a clear and systematic presentation of the findings. These sections aim to elucidate the complex interplay between dam development and its socio-economic consequences, ensuring a thorough understanding of stakeholder perspectives and the broader implications for the community. This chapter set forth a statistical investigation about opinions and perceptions of multi-stakeholders on socio-economic impacts induced due to Ranjit Sagar Dam in upstream region during its constructional as well as operational phase. The Socio-economic impacts are divided into broad themes such as Impacts on Livelihood, Infrastructure and Community as per Matrix Framework (Kirchherr& Charles, 2016) (Figure 4.1). These themes have various sub-components. Further, to assess the relationship between various demographic variables (Occupation, Age and Education) and socio-economic components, hypotheses testing has been done using Chi-Square Test. Thus, this chapter has following main sections and sub-sections:

4.1 Analysis of Socio-Economic Impacts in Upstream region of Ranjit Sagar dam during Constructional Phase.

4.2 Analysis of Socio-Economic Impacts in Upstream region of Ranjit Sagar Dam during Operational Phase.

4.1 Analysis of Socio-Economic Impacts in Upstream region of Ranjit Sagar Dam during Constructional Phase

This section deals with an analysis of three major components i.e. Impacts on Livelihood, Impact on Infrastructure and Impacts on Community. To assess the association of these components, the hypotheses testing has been done between their sub-components and demographic variables such as Occupation, Age and Education.

4.1.1 Association Between Demographic Variables (Occupation, Age and Education) and Perception for Impacts on Livelihood

4.1.1.1 Association between Occupation and Impact on Livelihood

From Table 4.1 to 4.5 below, it is possible to analyze the association between Occupation and Impact on Livelihood.

Observation: Table 4.1 depicts that most of the respondents who are dam employee agree (17.5%) or strongly agree (14.9%) that Ranjit Sagar Dam construction led to change in cropping pattern and decreased agricultural production in upstream region. To check the association between occupation and level of agreement on Changed cropping pattern and decreased agricultural production, we used Chi-square Test. From analysis, the chi-square value for 16 d. f. (degree of freedom) and p-value (.000) was found to be 56.316 which is significant at 1%. Thus, the hypothesis stands validated proving that there exists a statistically significant association between occupation and changed cropping pattern leading to decreased agricultural production and its impact on farming as livelihood.

Figure 4.1

Socio-Economic Impacts: Major Themes and Sub-components

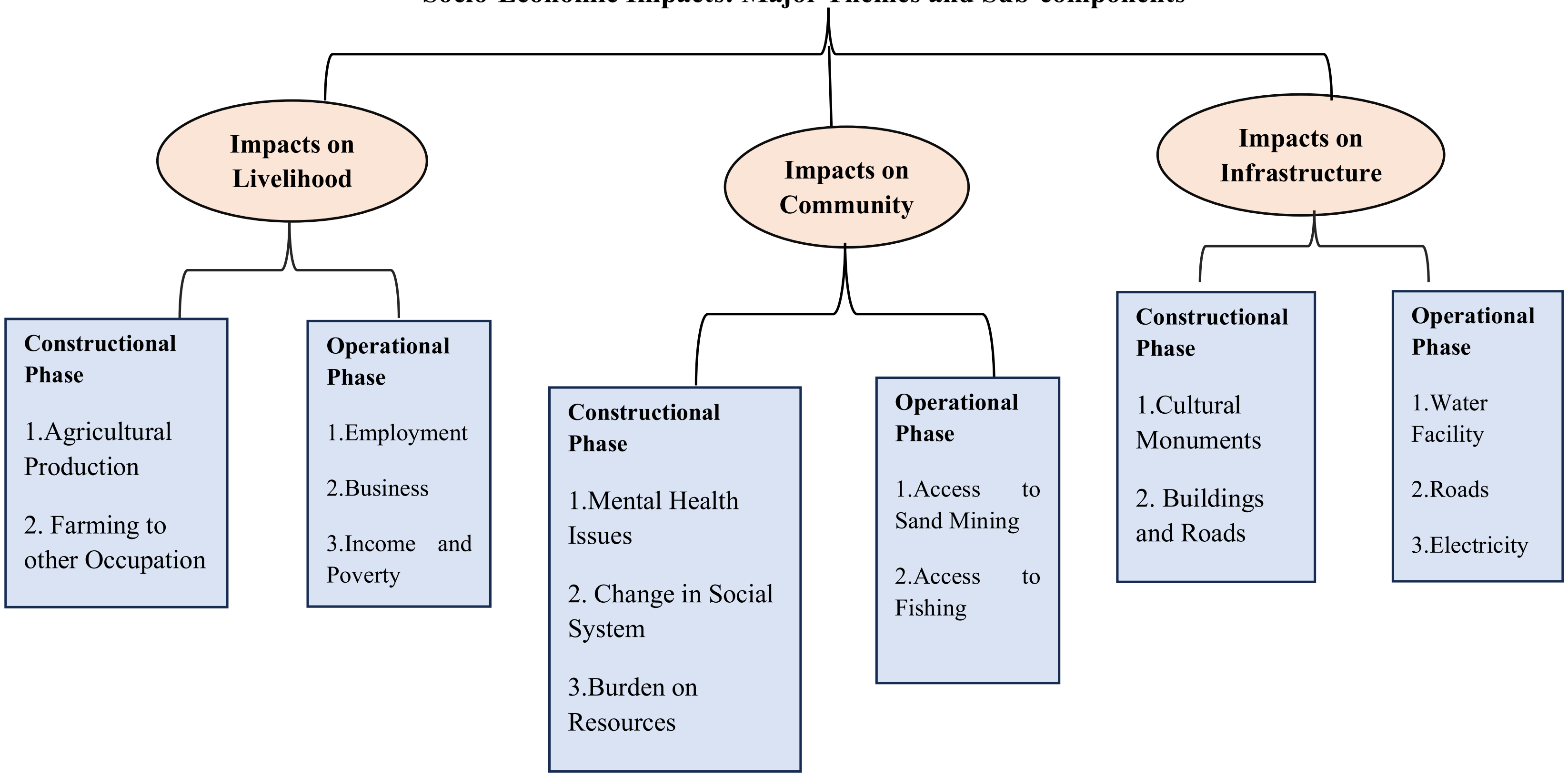


Table no. 4.1

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Changed Cropping Pattern/ Decreased Agricultural Production						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	1(0.3)	4(1.2)	19(5. 9)	57 (17.5)	48 (14.9)	125 (38.9)	56.316 ***
	Farmer	0(0)	1(0.3)	21(6.5)	35 (10.9)	17 (5.2)	74 (23)	
	Business	2(0.6)	0(0)	8(2.4)	18 (5.6)	7 (2.1)	35 (10.9)	
	Government Job	0(0)	0(0)	11(3.4)	20 (6.2)	24 (7.4)	55 (17.1)	
	Others	0(0)	7(2.1)	4(1.2)	11 (3.4)	10 (3.1)	32 (9.9)	
	Total	3(0.9)	12((3.7)	63(19.6)	141 (43.9)	102 (31.7)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: Table 4.2 depicts that 25.5% respondents agree and 19.6% of them strongly agreed that they practiced a shift from farming to labor for earning their livelihood during construction of Ranjit Sagar Dam. The research question being investigated is whether there is a significant relationship between the occupation and adopting labour as livelihood during dam construction. To investigate, we used Chi-square Test and it is clear from the analysis (Table 4.2) that Chi- square value for 16 d. f. (degree of freedom) and p-value (.000) is 62.101which has significance level at 1%, showing that the relationship between occupation and shift of livelihood from farming to labour during construction of Ranjit Sagar dam is statistically significant.

Table 4.2

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

	Occupation	Farming To Labor: Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	15 (4.6)	46 (14.3)	32 (9.96)	15 (4.6)	17 (5.29)	125 (38.9)	62.101 ***
	Farmer	0	11 (3.42)	23 (7.16)	19 (5.9)	21 (6.54)	74 (23.0)	
	Business	1 (0.3)	8 (2.49)	5 (1.5)	12 (3.7)	9 (2.8)	35 (10.9)	
	Government Job	1 (0.3)	4 (1.2)	17 (5.29)	23 (7.1)	10 (3.1)	55 (17.1)	
	Others	1 (0.3)	6 (1.8)	6 (1.8)	13 (4.0)	6 (1.8)	32 (9.96)	
		18 (5.60)	75 (23.3)	83 (25.8)	82 (25.5)	63 (19.6)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: The data given in Table 4.3, portrays the level of agreement or disagreement on shift of livelihood from farming to business during dam construction. About 80 (24.9%) respondents disagree and 32 (9.9%) strongly disagree for adopting business as livelihood. 87 (27.1%) respondents have neutral views about this question and 89 (27.8%) respondents agreed for adopting business as livelihood. Further, to check the association, we applied Chi-square test on the data and analysis shows that the Chi-square value for 16 d. f. (degree of freedom) and p-value (.000) is 47.938 which has significance level at 1%. Hence, it indicates that the relationship between occupation and adopting business as livelihood is statistically significant.

Table no.4.3

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

	Occupation	Farming To Business						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	18(5.6)	41(12.7)	41(12.7)	19	6(1.8)	125 (38.9)	47.938 ***
	Farmer	6(1.8)	21(6.5)	19(5.9)	20	8(2.4)	74 (23.8)	
	Business	3(0.9)	2(0.6)	5(1.5)	17(5.2)	7(2.1)	34 (10.9)	
	Government Job	2(0.6)	9(2.8)	18(5.6)	18	8(2.4)	55 (17.1)	
	Others	3(0.9)	7(2.1)	4(1.2)	15	3(0.9)	32 (9.9)	
	Total	32 (9.9)	80 (24.9)	87 (27.1)	89 (27.8)	32(9.9)	320 (100)	

() represents percentage and *** represents significance level at 1%

Observation: The data depicted in Table 4.4 illustrates the level of agreement or disagreement on shift of livelihood from practicing farming to Dam employee. About 91(28.3%) respondents strongly agreed for a shift in livelihood from farming to have a job in Ranjit Sagar dam offices followed by 43(13.3%) respondents who agreed for the same. On the other hand, about 69 (21.4%) and 68 (21.1%) respondents strongly disagreed and disagreed for the same. To check the association between occupation and getting a job in dam office, we applied Chi-Square test. The result of the test as shown in the Table 4.4 indicates that the value of Chi-square for 16 d. f. (degree of freedom) and p-value (.000) is 73.238 having significance at 1%. Thus, hypothesis stands validated. We conclude that there exists a significant relationship between occupation and getting employed in dam office during dam construction.

Table no. 4.4

Ranjit Sagar Dam and Upstream Region: Association Between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Job in Dam Office						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	23(7.1)	9(2.8)	15(4.6)	15(4.6)	63(19.6)	125 (38.9)	73.238 ***
	Farmer	17(5.2)	25(7.7)	11(3.4)	7(2.1)	14(4.3)	74 (23.0)	
	Business	9(2.8)	9(2.8)	6(1.8)	9(2.8)	2(0.6)	35 (10.9)	
	Government Job	15(4.6)	14(4.3)	15(4.6)	6(1.8)	5(1.5)	55 (17.1)	
	Others	5(1.5)	11(3.4)	3(0.9)	6(1.8)	7(2.1)	32 (9.9)	
	Total	69(21.4)	68(21.1)	50(15.5)	43(13.3)	91(28.3)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: According to the Table no.4.5, the level of agreement or disagreement shows that majority of the respondents i.e. 102 (31.7%) and 77(23.9%) respondents disagree and strongly disagree respectively on increase in Government jobs during Ranjit Sagar Dam construction. A small number of respondents 4 (1.2%) strongly agreed for getting government jobs during constructional phase of Ranjit Sagar dam. To test the significance, Chi-Square test was applied and results as given in Table 4.5, shows that Chi-square value for 16 d. f. (degree of freedom) and p-value (.048) is significant at 5%. Thus, there exist significant relationship between occupation and shift of livelihood from farming to Govt. Job.

Table no.4.5

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Farming To Govt. Job						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	26(8.0)	43(13.3)	50(15.5)	6(1.8)	1(0.3)	125 (38.9)	26.434 **
	Farmer	19(5.9)	20(6.2)	26(8.09)	8(2.4)	0(0)	74 (23.0)	
	Business	7(2.1)	12(3.7)	9(2.8)	5(1.5)	2(0.6)	35 (10.9)	
	Government Job	20(6.2)	14(4.3)	19(5.9)	2(0.6)	0(0)	55 (17.1)	
	Others	5(1.5)	13(4.0)	12(3.7)	1(0.3)	1(0.3)	32 (9.9)	
	Total	77(23.9)	102(31.7)	116(36.1)	22(6.8)	4(1.2)	321 (100)	

() represents percentage and ** represents significance level at 5%

4.1.1.2 Association between Age and Impacts on Livelihood:

From the data provided in the Table 4.6 to 4.10, the association between Age Group and Impacts on Livelihood can be analyzed.

Observation: The data in Table 4.6 is depicting the level of agreement or disagreement of upstream respondents of different age groups regarding changed cropping pattern and decrease in agricultural production during constructional phase of Ranjit Sagar Dam. The data shows that majority of the respondents i.e. 141(43.9%)/ 102(31.7%) agreed/strongly agreed that there was a decrease in agricultural production during construction of Ranjit Sagar Dam. To test the significance, we applied Chi-square test and as the result shows (Table 4.6) the Chi-square value for 8 d. f. (degree of freedom) and p-value (.002) found to be 24.90 which has significance level at 1%. Therefore, there exists statistically significant relationship between Age group and changed cropping pattern and consequent decrease in agricultural production during constructional phase of Ranjit Sagar Dam.

Table no. 4.6

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Livelihood (Construction Phase)

Age		Changed Cropping Pattern/ Decreased Agricultural Production						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	1(0.3)	8(2.4)	33(10.2)	76(23.6)	57(17.7)	175 (54.5)	24.90***
	36-50	0(0)	4(1.2)	16(4.9)	53(16.5)	39(12.1)	112 (34.9)	
	25-35	2(0.6)	0(0)	14(4.3)	12(3.7)	6(1.8)	34 (10.6)	
	Total	3(0.3)	12(3.7)	63(19.6)	141(43.9)	102(31.7)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: Table 4.7 depicts the level of agreement or disagreement of upstream respondents of different age groups regarding change in livelihood from farming to labor during constructional phase of Ranjit Sagar Dam. The data shows that majority of the respondents i.e. 82(25.5%) and 63 (19.6%) agreed and strongly agreed respectively that there was a shift of livelihood from farming to labor during construction of Ranjit Sagar Dam. To test the significance, we applied Chi-square test and as the result shows (Table 4.7) that for 8 d. f. (degree of freedom) and p-value (.002), the Chi-square value found to be 24.465 which has significance level at 1%. Therefore, there exists statistically significant relationship between Age group and adopting labor as a means of livelihood during constructional phase of Ranjit Sagar Dam.

Table no. 4.7

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Livelihood (Construction Phase)

Age		Farming To Labor						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	12(3.7)	52(16.1)	44(13.7)	38(11.8)	29(9.0)	175 (54.5)	24.465***
	36-50	0(0)	3(0.9)	13(4.0)	15(4.6)	31(9.6)	34 (10.5)	
	25-35	6(1.8)	20(6.2)	0(0)	29(9.0)	3(0.9)	112 (34.8)	
	Total	18(5.6)	75(23.3)	83(25.8)	82(25.5)	63(19.6)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: Table 4.8 shows that about 28 % respondents of different age groups agreed that there was a shift of livelihood from farming to business followed by 80(24.9%) respondents who did not perceive exactly same about adopting business as new livelihood. Further, Chi-Square test was applied to check the significance of relationship between age group and adopting business as new livelihood. As the results indicate in (Table 4.8), the value of Chi-Square for 8 degrees of freedom and p-value (.000) is 31.220 which is significant at 1% confirming that there exists significant relationship between age group and changing livelihood from farming to business.

Observation: The data depicted in Table 4.9 illustrates the level of agreement or disagreement on shift of livelihood from practicing farming to Dam employee. About 91(28.3%) respondents strongly agreed for a shift in livelihood from farming to have a job in Ranjit Sagar dam office followed by 43(13.3%) respondents who agreed for the same. On the other hand, about 69 (21.4%) and 68 (21.1%) respondents strongly disagreed and disagreed for the same. To check the association between Age group and getting a job in dam office, we applied Chi-Square test. The result of the test as shown in the Table 4.9 indicates that the Chi-square value for 8 degrees of freedom and p-value (.002) is 25.080 which has significance level at 1%. Thus, there exists a significant relationship between Age group and getting employed in dam office during dam construction.

Table 4.8

Ranjit Sagar Dam and Upstream Region : Association between Age Group and Impact on Livelihood (Construction Phase)

Age		Farming To Business						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	19(5.9)	55(17.1)	51(15.8)	42(13.0)	8(2.4)	175 (54.5)	31.220***
	36-50	13(4.0)	19(5.9)	31(9.6)	30(9.3)	19(5.9)	112 (34.8)	
	25-35	0(0)	6(1.8)	5(1.5)	18(5.6)	5(1.5)	34 (10.5)	
	Total	32(9.9)	80(24.9)	87(27.1)	90(28.0)	32(9.9)	321 (100)	

() represents percentage and *** represents significance level at 1%

Table no. 4.9

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Livelihood (Construction Phase)

Age		Farming To Job in Dam Office						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	28(8.7)	33(10.2)	28(8.7)	21(6.5)	65(20.2)	175 (54.5)	25.080***
	36-50	34(10.5)	27(8.4)	12(3.7)	17(5.2)	22(6.8)	112 (34.8)	
	25-35	7(2.2)	8(2.4)	10(3.1)	5(1.5)	4(1.2)	34 (10.5)	
	Total	69(21.4)	68(21.1)	50(15.5)	43(13.3)	91(28.3)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: According to the Table no.4.10, the responses on level of agreement or disagreement shows that majority of the respondents i.e. 102(31.7%) and 77(23.9%) respondents disagreed and strongly disagreed respectively on increase in Government jobs during Ranjit Sagar Dam construction. A small number of respondents 4(1.2%) strongly agreed for getting government jobs during constructional phase of Ranjit Sagar dam. To test the significance, Chi-Square test was applied and results as given in Table 4.10, shows that Chi-square value for 8 degrees of freedom and p-value (.001) is 26.570 which is significant at 1% level. Thus, there exists statistically significant relationship between Age group and shift of livelihood from farming to Govt. Job.

Table no. 4.10

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Livelihood (Construction Phase)

Age		Farming To Govt. Job						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	26(8.0)	60(18.6)	73(22.7)	13(4.0)	3(0.9)	175 (54.5)	26.570***
	36-50	43(13.3)	33(10.2)	26(8.0)	8(2.4)	1(0.3)	112 (34.8)	
	25-35	8(2.4)	9(2.8)	16(4.9)	1(0.3)	0(0)	34 (10.5)	
	Total	77(23.9)	102(31.7)	115(35.8)	22(6.8)	4(1.2)	321 (100)	

() represents percentage and ***represents level of significance at 1%

Since all the sub-components under the theme 'Impacts on Livelihood' are statistically associated with Occupation and Age Group, indicating that during construction phase of Ranjit Sagar Dam, there was significant decrease in agricultural production and consequent shift of the means of livelihood from farming to other occupations.

4.1.1.3 Association between Education and Impact on Livelihood

The association between sub-components and education is not statistically significant.

4.1.2 Association Between Demographic Variables (Occupation, Age and Education) and Perceptions for Impacts on Infrastructure

It was found that there does not exist statistically significant association between all categorical variables and perceptions regarding Impacts on Infrastructure.

4.1.3. Association Between Demographic Variables (Occupation, Age and Education) and Perceptions for Impacts on Community

4.1.3.1 Association between Occupation and Impacts on Community

The association between all sub-components and occupation is not statistically significant.

4.1.3.2 Association of Age and Impact on Community

Observation: Table 4.11 portrays the description about level of agreement or disagreement for increase in mental health issues during dam constructional phase. According to the data given in the table, most of the respondents 127(39.5%) have neutral views followed by 102(31.7%) respondents who agree that mental health issues increased among upstream people during construction of Ranjit Sagar Dam. We applied Chi-Square test to check the if there is significant relationship between Occupation and Increase in Conflicts. Result shows (Table 4.11) that the Chi-Square value for 8 degrees of freedom and p-value (.000) is 30.601 which is significant at 1%. Therefore, the association between Age group and Increased Mental Health issues is statistically significant.

Observation: As shown in Table no.4.12, the data is about respondent's level of agreement or disagreement regarding burden on resources during construction of Ranjit Sagar Dam. As illustrated in the Table 4.12, majority of the respondents i.e. about 127(39.6%) agreed that there was burden on resources due to dam construction. Further to verify the significance of relationship between occupation and burden on resources, we used Chi-Square test, and its value for 8 degrees of freedom and p-value (.000) found to be 49.655 which has significance level at 1%. Hence, it is clear that there is significant association between Age group and level of agreement for burden on resources.

Table no. 4.11

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Community (Construction Phase)

Age		Increased mental Health Issues						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	4(1.3)	24(7.4)	71(22.1)	54(16.8)	21(6.5)	174 (54.5)	30.601***
	36-50	3(0.9)	11(3.4)	39(13.0)	41(12.7)	18(5.6)	112 (34.8)	
	25-35	0(0)	15(4.6)	11(3.4)	7(2.1)	0(0)	33 (10.3)	
	Total	7(0.9)	50(15.5)	121 (39.5)	102 (31.7)	39(12.1)	319 (100)	

() represents percentage and *** represents significance level at 1%

Table no.4.12

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Community (Construction Phase)

Age		Burden on Resources						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	0(0)	16(4.9)	70(21.8)	69(21.4)	20(6.2)	175 (54.5)	49.655***
	36-50	0(0)	2(0.6)	51(15.8)	48(14.9)	11(3.4)	112 (34.8)	
	25-35	1(0.3)	13(4.0)	8(2.4)	10(3.1)	2(0.6)	34 (10.5)	
	Total	1(0.3)	31(9.7)	129(40.2)	127 (39.6)	33(10.3)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: According to the Table no.4.13, the data on level of agreement or disagreement shows that majority of the respondents i.e. 121(37.6%) neither disagree nor agree on Increased conflicts among upstream people during dam construction followed by 115(35.8%) and 32(9.9%) respondents who agreed and strongly agreed respectively on increased conflicts during Ranjit Sagar Dam construction. Only 12(3.7%) respondents strongly disagreed for the same. To test the significance, Chi-Square test was applied and results as given in Table 4.13, shows that Chi-square value for 8 degrees of freedom and p-value (.000) is 39.933 which is significant at 1%. Thus, there exist statistically significant relationship between Age Group and Increased conflicts.

Table no. 4.13

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Community (Construction Phase)

Age		Increased Conflicts						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	3(0.9)	22(6.8)	70(21.8)	60 (18.6)	20(6.2)	175 (54.5)	39.933***
	36-50	4(1.2)	7(2.1)	44(13.7)	46 (14.3)	11(3.4)	112 (34.8)	
	25-35	5(1.5)	12(3.7)	7(2.1)	9 (2.8)	1(0.3)	34 (10.5)	
	Total	12(3.7)	41(12.7)	121 (37.6)	115 (35.8)	32(9.9)	321 (100)	

() represents percentage and *** represents significance level at 1%

4.1.3.3 Education and Impact on Community

After analysis, it was found that all the results for all sub-components of component 'Community' and Education level are not significant indicating that there is absence of statistically significant relationship between Education level and perceptions regarding Impacts on Community.

4.2 Analysis of Impacts on Livelihood, Infrastructure and Community during Operational Phase of Ranjit Sagar Dam Project

In this section, we analyse how various categorical variables—specifically Occupation, Age, and Education Level—interact with and influence the impacts on Livelihood, Infrastructure, and Community during the operational phase of a project.

4.2.1. Association between Demographic variables (Occupation, Age and Education) and Perceptions regarding Impacts on Livelihood

4.2.1.1 Association between Occupation and Impacts on Livelihood

First of all, we have categorized Livelihood under different components namely Employment, Business flourishment, Income and Reduction in Poverty. To analyze the Impacts on Livelihood and its relationship with categorical variable 'Occupation, we applied Chi-square test.

Observation: Table 4.14, outlines the level of agreement or disagreement of Upstream respondents regarding Increase in Employment during operational phase. The data specified here shows that almost equal number of respondents agree and disagree. About 24.9% respondents agreed that there was increase in employment during operational phase of Ranjit Sagar Dam. On the other hand, 19.6% respondents disagreed for the same. To verify the significance, we applied Chi-Square test and result (Table no.4.14) shows its value for 16 degrees of freedom and p-value (.001) is 39.707 which is significant at 1%. For that reason, it is concluded that association between Occupation and increase in Employment during operational phase is statistically significant.

Observation: The data in Table no.4.15 represents respondent's agreement or disagreement on Rise in income level and Reduction in Poverty during operational phase of Ranjit Sagar Dam. It is clearly illustrated from the below given Table 4.15 that almost equal number of the respondents (83 or 25.9%) and (81 or 25.2%) agreed and disagreed respectively for the above-mentioned component. To check whether the association between the occupation and the component (as mentioned in Table 4.15), we used Chi-square Test wherein its value for 16 degrees of freedom and p-value (.02) found to be 28.340 which has significance level at 5% pointing that there is significant relationship between the occupation and Rise in Income level and reduced poverty after Ranjit Sagar Dam construction.

Table no. 4.14

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Community (Operational Phase)

Occupation		Increased Employment in Your Area						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	18(5.6)	20(6.2)	26(8.0)	38 (11.8)	23(7.1)	125 (38.9)	39.707 ***
	Farmer	17(5.2)	22(6.8)	12(3.7)	19 (5.9)	4(1.2)	74 (23)	
	Business	5(1.5)	7(2.1)	9(2.8)	10 (3.1)	4(1.2)	35 (10.9)	
	Government Job	13(4.0)	8(2.4)	26(8.0)	6 (1.8)	2(0.6)	55 (17.1)	
	Others	7(2.1)	6(1.8)	7(2.1)	7(2.1)	5(1.5)	32 (9.9)	
	Total	60(18.6)	63(19.6)	80 (24.9)	80 (24.9)	38(11.8)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: According to the data set forth in the Table no. 4.16, respondent's level of agreement or disagreement towards burgeoning business or market after dam construction is described. Majority of the respondents i.e. 100 (31.2%) show disagreement for any growth of business during operational phase of Ranjit Sagar Dam. But significant number of respondents, about 70(21.8%) also agreed that markets and business in their area flourished during the operational phase of dam. We used Chi-square test to verify the significant relationship between occupation and Business flourishment. Chi-square value found to be 77.612 which has significance level at 1% indicating that there is significant association between Occupation and level of agreement or disagreement on business growth.

Table no. 4.15

Ranjit Sagar Dam and Upstream Region: Association of Occupation and Impacts on Livelihood (Operational Phase)

Occupation		Rise In Income and Reduction in Poverty						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	13(4.0)	26(8.1)	29(9.0)	37 (11.5)	20(6.2)	125 (38.9)	28.340 **
	Farmer	12(3.7)	23(7.2)	16(5.0)	17(5.3)	6(1.9)	74 (23)	
	Business	2(0.6)	8(2.4)	12(3.7)	11(3.4)	2(0.6)	35 (10.9)	
	Government Job	7(2.2)	17(5.3)	23(7.2)	8(2.4)	0(0)	55 (17.1)	
	Others	5(1.5)	7(2.2)	7(2.2)	10(3.1)	3(0.9)	32 (9.9)	
	Total	39(12.1)	81(25.2)	87(27.1)	83 (25.9)	31(9.7)	321 (100)	

() represents percentage and ** represents significance level at 5%

4.2.1.2 Age and Impact on Livelihood

In this section, the relationship between categorical variable 'Age' and Impact on Livelihood is analyzed.

Observation: Table no.4.17 depicts the data about upstream respondent's agreement or disagreement for Increase in employment during operational phase. Almost equal number of respondents have agreement and disagreement for the question. 123 respondents either strongly disagree or disagree and 118 respondents either strongly agree or agree that employment increased in their region after dam construction. To test the association between Age and Increased employment, Chi-square test was applied and results show the Chi-square value for 8 degrees of freedom and p-value (.001) is 27.235 which is significant at 1%. Hence, Age group and Increased employment are significantly associated with each other.

Table no. 4.16

Ranjit Sagar Dam and Upstream region: Association of Occupation and Impact on Livelihood (Operational Phase)

Occupation		Business Flourished						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	10(3.1)	29(9.0)	38(11.8)	37 (11.5)	11(3.4)	125 (38.9)	77.612 ***
	Farmer	8(2.5)	38(11.8)	13(4.0)	6 (1.8)	9(2.8)	74 (23)	
	Business	2(0.6)	3(0.9)	4(1.2)	21 (6.5)	5(1.5)	35 (10.9)	
	Government Job	8(2.5)	21(6.6)	21(6.6)	2 (0.6)	3(0.9)	55 (17.1)	
	Others	2(0.6)	9(2.8)	12(3.7)	4 (1.2)	5(1.5)	32 (9.9)	
	Total	30(9.3)	100(31.2)	88(27.4)	70 (21.8)	33(10.3)	321 (100)	

() represents percentage and *** represents significance level at 1%

Table no. 4.17

Ranjit Sagar Dam and Upstream Region: Association of Age and Impact on Livelihood (Operational Phase)

Age		Increased Employment in Your Area						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	26(8.0)	27(8.4)	49(15.2)	50(15.5)	23(7.1)	175 (54.5)	27.235***
	36-50	29(9.0)	31(9.6)	18(5.6)	24(7.4)	8(2.4)	112 (34.8)	
	25-35	5(1.5)	3(0.9)	13(4.0)	6(1.8)	7(2.1)	34 (10.5)	
	Total	60(18.7%)	63 (19.6%)	80 (24.9%)	80(24.9%)	38 (11.8%)	321 (100)	

() represents percentage and *** represents significance level at 1%

The data in Table no.4.18 represents respondent's agreement or disagreement on Rise in income level and Reduction in Poverty during operational phase of Ranjit Sagar Dam. It is clearly illustrated from the below given Table 4.18 that almost equal number of the respondents (83 or 25.8%) and (81 or 25.2%) agree and disagree respectively for the above-mentioned component. To check whether the association between the occupation and the component (as mentioned in Table 4.18), we used Chi-square Test wherein its value for 8 degrees of freedom found to be 28.600 which has significance level at 1% pointing that there is significant relationship between the occupation and Rise in Income level and reduced poverty after Ranjit Sagar Dam Construction

Table 4.18

Ranjit Sagar Dam and Upstream Region: Association of Age Group and Impact on Livelihood (Operational Phase)

		Rise in Income Level and reduction in Poverty						
Age		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	12(3.7)	41(12.7)	45(14.0)	53(16.5)	24(7.4)	175 (54.5)	28.600***
	36-50	25(7.7)	33(10.2)	29(9.0)	20(6.2)	5(1.5)	112 (34.8)	
	25-35	2(0.6)	7(2.1)	13(4.0)	10(3.1)	2(0.6)	34 (10.5)	
	Total	39(12.1)	81(25.2)	87(27.1)	83(25.8)	31(9.6)	321 (100)	

() represents percentage and *** represents significance level at 1%

Table 4.19 depicts association between Age group and level of agreement or disagreement on growth of Business during operational phase of Ranjit Sagar Dam. To assess the relationship between Age group and level of agreement on business flourishment, Chi-square Test has been used. The analysis shows that the value of Chi-square for 8 d. f. (Degree of Freedom) and p-value (.09) is 13.483 which is statistically significant at 10% level. Thus, it is validated that there exists a significant relationship between Age group and level of agreement or disagreement growth of business after dam construction.

Table 4.19

Ranjit Sagar Dam and Upstream Region: Association of Age Group and Impacts on Livelihood (Operational Phase)

	Age	Business Flourished						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	16(4.9)	54(16.8)	47(14.6)	43(13.3)	15(4.6)	175 (54.5)	13.483*
	36-50	14(4.3)	34(10.5)	34(10.5)	20(6.2)	10(3.1)	112 (34.8)	
	25-35	0(0)	12(3.7)	7(2.1)	7(2.1)	8(2.4)	34 (10.5)	
	Total	30(9.3)	100(31.2)	88(27.4)	70(21.8)	33(10.2)	321 (100)	

() represents percentage and * represents level of significance at 10%

4.2.1.3 Education and Impact on Livelihood:

Most of the sub-components under this section are not significantly associated with Education level indicating no association between education level and perceptions regarding Impacts on Livelihood.

4.2.2 Analysis of Impacts on Infrastructure

4.2.2.1 Association between Occupation and Impact on Infrastructure

Observation: Table 4.20 shows the level of agreement for Improvement in roads during operational phase of Ranjit Sagar dam. To assess the relationship between Occupation and Impact on Roads improvement, we used Chi-Square Test. The analysis shows that for 16 degrees of freedom and p-value (.000), chi-square found to be 51.346 which is significant at 1%. Thus, the hypothesis stands validated. Thus, there exists a significant association between Occupation and level of agreement on Improved roads after the construction of Ranjit Sagar Dam. The data in Table 4.20 also depicts that majority of the respondents believed that there is no improvement in road infrastructure in upstream region after the construction of dam and as this is statistically proved, thus it is generalized that Ranjit Sagar Dam did not contribute much towards the road improvement in upstream region.

Table 4.20

Ranjit Sagar Dam and Upstream Region: Association of Occupation and Impacts on Infrastructure (Operational Phase)

Occupation		Improved Roads						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	21(6.5)	34(10.6)	15(4.7)	44(13.7)	11 (3.4)	125 (38.9)	51.346 ***
	Farmer	15(4.7)	39(12.1)	9(2.8)	8(2.5)	3(0.9)	74 (23)	
	Business	3(0.9)	11(3.4)	6(1.9)	14(4.4)	1(0.3)	35 (10.9)	
	Government Job	19(5.9)	28(8.7)	3(0.9)	5(1.6)	0(0)	55 (17.1)	
	Others	7(2.2)	15(4.7)	4(1.2)	5(1.6)	1(0.3)	32 (9.9)	
	Total	65(20.2)	127 (39.6)	37(11.5)	76(23.7)	16(5.0)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: Table 4.21 shows the level of agreement for Improvement in Drinking Water Facility in upstream region during operational phase of Ranjit Sagar dam. To assess the relationship between Occupation and Impact on Drinking water facility improvement, we used Chi-Square Test. The analysis shows that for chi-square value for 16 degrees of freedom and p-value (.000) is 48.441 which is significant at 1%. Thus, the hypothesis stands validated. Further as the Table 4.21 illustrates that majority of the respondents perceived that drinking water facility did not get better in upstream region after the construction of Ranjit Sagar Dam and same is statistically validated, thus it can be asserted that there was no improvement in water facilities in upstream region due to Ranjit Sagar Dam construction.

Table 4.21

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Impact on Infrastructure (Operational Phase)

Occupation		Improved Drinking Water Facility: Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	24(7.5)	34(10.6)	26(8.1)	34 (10.6)	7(2.2)	125 (38.9)	48.441***
	Farmer	25(7.8)	34(10.6)	8(2.5)	5(1.6)	2(1.2)	74 (23)	
	Business	3(0.9)	15(4.7)	7(2.2)	8(2.5)	2(1.2)	35 (10.9)	
	Government Job	21(6.5)	27(8.4)	5(1.6)	2(0.6)	0(0)	55 (17.1)	
	Others	9(2.8)	12(3.7)	7(2.2)	3(0.9)	1(0.3)	32 (9.9)	
	Total	82(25.5)	122(38.0)	53(16.5)	52 (16.2)	12(3.7)	321 (100)	

() represents percentage and *** represents significance at 1%

Observation: Table 4.22 shows the level of agreement for Opening of New Schools and Colleges during operational phase of Ranjit Sagar dam. Majority of the respondents (122) disagreed about opening of new schools and colleges in the upstream region after the dam construction. To assess the relationship between Occupation and Impact on opening of new schools and colleges, we used Chi-Square Test. The analysis shows that for 16 degrees of freedom and p-value (.004), chi-square value is 34.637 which is significant at 1%. Thus, the hypothesis stands validated. Hence it is affirmed that in upstream region the educational infrastructure did not get upgraded after the construction of Ranjit Sagar Dam.

4.2.2.2 Age Group and Impact on Infrastructure

Observation: Table 4.23 shows the level of agreement for improved water facility during operational phase of Ranjit Sagar dam. To assess the relationship between Age group and Impact on Drinking water facility, we used Chi-Square Test. The analysis shows that chi-square value for 8 degrees of freedom and p-value (.001) is 25.767 which is significant at 1%. Thus, the hypothesis stands validated. Moreover, the majority of the respondents (127) out of 321, believed that Road infrastructure did not improve much after the dam was built and the same is statistically proved leading to generalization about no significant improvement in road infrastructure.

Table no. 4.22

Ranjit Sagar dam and Upstream Region: Association of Occupation and Impacts on Infrastructure (Operational Phase)

	Occupation	New Schools and Colleges						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	16(5.0)	39(12.6)	38(11.9)	24(7.5)	5(1.6)	125 (38.9)	34.637 ***
	Farmer	6(1.9)	32(10.1)	33(10.4)	3(0.9)	0(0)	74 (23)	
	Business	3(0.9)	10(3.1)	14(4.4)	7(2.2)	1(0.3)	35 (10.9)	
	Government Job	12(3.8)	27(8.5)	13(4.1)	3(0.9)	0(0)	55 (17.1)	
	Others	5(1.6)	13(4.1)	11(3.5)	2(0.6)	0(0)	32 (9.9)	
	Total	42(13.2)	122 (38.4)	109 (34.3)	39 (12.3)	6(1.9)	321 (100)	

() represents percentage and *** represents significance level at 1%

Observation: Table 4.24 shows the level of agreement for Improvement in drinking water facility during operational phase of Ranjit Sagar dam. The data depicts that most of the respondents (122) perceived that Ranjit Sagar dam has no positive impact on Drinking water facility. To assess the relationship between Age group and Impact on Drinking water Facility, we used Chi-Square Test. The analysis shows that chi-square value for 8 degrees of freedom and p-value (.001) is 33.82 which is significant at 1%. Thus, the hypothesis stands validated.

Table 4.23

Ranjit Sagar dam and Upstream Region: Association of Age and Impacts on Infrastructure (Operational Phase)

Age		Improved Roads						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	24(7.5)	62(19.3)	22(6.9)	55 (17.1)	12(3.7)	175 (54.5)	25.767***
	36-50	31(9.7)	48(15.0)	10(3.1)	19(5.9)	4(1.2)	112 (34.9)	
	25-35	10(3.1)	17(5.3)	5(6.9)	2(0.6)	0(0)	34 (10.6)	
	Total	65(20.2)	127(39.6)	37(11.5)	76 (23.6)	16(5.0)	321 (100)	

() represents percentage and *** represents significance level at 1%

Table 4.24

Ranjit Sagar Dam: Association of Age Group and Impacts on Infrastructure

Age		Improved Drinking Water Facility						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	35(10.9)	55(17.1)	39(12.1)	36(11.2)	10(3.1)	175 (54.5)	33.82**
	36-50	35(10.9)	51(15.9)	11(3.4)	13(4)	2(0.6)	112 (34.9)	
	25-35	12(3.7)	16(17.1)	3(0.9)	3(0.9)	0(0)	34 (10.6)	
	Total	82(25.5)	122(38)	53(16.5)	52(16.2)	12(3.7)	321 (100)	

() represents percentage and ** represents significance level at 5%

Observation: Table 4.25 shows the level of agreement for Improvement in Schools and Colleges during operational phase of Ranjit Sagar dam. Most of the respondents belonging to Age group >50 either disagreed or strongly disagreed about opening of new schools and colleges in operational phase of Ranjit Sagar Dam Project. To assess the relationship Age group and Impact on opening of new schools and colleges, we used Chi-Square Test. The analysis shows that for chi-square value for 8 degrees of freedom and p-value (.02) is 17.657 which is significant at 5%. Thus, the hypothesis stands validated.

Table 4.25

Ranjit Sagar Dam and Upstream Region: Association of Age Group and New schools and Colleges (Operational Phase)

Age		New School and Colleges						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	17(5.3)	60(18.9)	63(19.8)	27 (8.5)	5(1.6)	172 (54.1)	17.657 **
	36-50	23(7.3)	49(15.3)	31(9.7)	8(2.5)	1(.3)	112 (35.2)	
	25-35	2(0.6)	13(4.1)	15(4.7)	4(8.5)	0(0)	34 (10.7)	
	Total	42(13.2)	122(38.4)	109(34.3)	39 (12.3)	6(1.9)	318 (100)	

() represents percentage and ** represents significance level at 5%

4.2.2.3 Education and Impact on Infrastructure

All sub-components are not associated significantly with Education level. Thus, there exists no relationship between Education level and level of agreement for Impacts on Infrastructure.

4.2.3 Association between demographic variables (Occupation, Age and Education) and perceptions regarding Impacts on Community

4.2.3.1 Occupation and Impact on Community

Observation: Table 4.26 shows the level of agreement for access to sand mining during operational phase of Ranjit Sagar dam. To assess the relationship between occupation and impact on access to sand mining, we used Chi-Square Test. The analysis shows that for 16 degrees of freedom and p-value (.000), the chi-square value is 62.420 which is significant at 1%. Thus, the hypothesis stands validated. Results indicate that majority of respondents (about 215 out of 321) either show strong disagreement or disagreement regarding access to sand mining during operational phase. Exceptionally, some of the dam employees show agreement for access to sand mining indicating that some dam employees have special access to these resources.

Table 4.26

Ranjit Sagar Dam and Upstream Region: Association of Occupation and Impact on Community (Operational Phase)

Occupation		Access of Sand Mining						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	24(7.5)	35(10.9)	30[(9.3)	31(9.6)	5(1.6)	125 (38.9)	62.420 ***
	Farmer	25(7.8)	38(11.8)	10(3.1)	1(0.6)	0(0)	74 (23)	
	Business	4(1.2)	17(5.3)	8(2.5)	5(1.6)	1(0.3)	35 (10.9)	
	Government Job	21(6.5)	28(8.7)	5(1.6)	1(0.3)	0(0)	55 (17.1)	
	Others	9(2.8)	14(4.4)	8(2.5)	1(0.3)	0(0)	32 (9.9)	
	Total	83(25.9)	132 (41.1)	61(19.0)	39 (12.1)	6(1.9)	321 (100)	

() represents percentage and *** represents level of significance at 1%

Observation: Table 4.27 shows the level of agreement for access to fishing during operational phase of Ranjit Sagar dam. There is a total of 321 respondents across various occupations, with a majority indicating disagreement with having access to fishing (42.7% disagree and 19.9% strongly disagree). To assess the relationship between Occupation and Impact on access for Fishing, we used Chi-Square Test. The analysis shows that for 16 degrees of freedom and p-value (.000), the value of Chi-square is 52.221 which is significant at 1%. Thus, the hypothesis stands validated.

4.2.3.2 Age and Impact on Community

Observation: Table 4.28 shows the level of agreement for access to sand mining during operational phase of Ranjit Sagar dam. Out of 321 respondents, most of the them have either strong disagreement (25.9%) or disagreement (41.1%) regarding access to Sand Mining with people from >50 and 36-50 age groups show only small difference. To assess the relationship between Age Group and Impact on access to Sand Minig, we used Chi-Square Test. The analysis shows that for 8 degrees of freedom and p-value (.012), the value of Chi-square is 19.539 which is significant at 5%. Thus, the hypothesis stands validated.

Table 4.27

Ranjit Sagar Dam and Upstream Region: Association between Occupation and Access to Fishing (Operational Phase)

		Access to Fishing						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	21(6.5)	37(11.5)	25(7.8)	33 (10.3)	9(2.8)	125 (38.9)	52.221 ***
	Farmer	14(4.4)	43(13.4)	8(2.5)	5(1.6)	4(1.2)	74 (23)	
	Business	3(0.9)	12(3.7)	5(1.6)	13(4.0)	2(0.6)	35 (10.9)	
	Government Job	19(5.9)	29(9.0)	4(1.2)	3(0.9)	0(0)	55 (17.1)	
	Others	7(2.2)	16(5.0)	6(1.9)	2(0.6)	1(0.3)	32 (9.9)	
	Total	64(19.9)	137 (42.7)	48(15.0)	56 (17.4)	16(5.0)	321 (100)	

() represents percentage and *** represents level of significance at 1%

Observation: Table 4.29 shows the respondents level of agreement for access to Fishing during operational phase of Ranjit Sagar dam. To assess the relationship between Occupation and Impact on access to Fishing, we used Chi-Square Test. The analysis shows that for 8 degrees of freedom and p-value (.001), the value of Chi-square is 25.418 which is significant at 1%. Thus, the hypothesis stands validated indicating that there exists significant association between Age Group and level of agreement/disagreement regarding Impact on access to fishing. From Table 4.29, it is clear that 201 upstream respondents opined that they have no access to fishing during operational phase of Ranjit Sagar Dam.

Table 4.28

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Community (Operational Phase)

Age		Access to Sand Mining						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	36(11.2)	64(19.9)	40(12.5)	30(9.3)	5(1.6)	175 (54.5)	19.539**
	36-50	36(11.2)	52(16.2)	17(5.4)	6(1.9)	1(0.1)	112 (34.9)	
	25-35	11(3.4)	16(5)	4(1.2)	3(.09)	0(0)	34 (10.6)	
	Total	83(25.9)	132(41.1)	61(19)	39 (12.1)	6(1.9)	321 (100)	

() represents percentage and ** represents level of significance at 5%

Table 4.29

Ranjit Sagar Dam and Upstream Region: Association between Age Group and Impact on Community (Operational Phase)

Age		Access to Fishing						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	24(7.5)	66(20.6)	31(9.7)	41 (12.8)	13(4.0)	175 (54.5)	25.418***
	36-50	30(9.3)	54(16.8)	12(3.7)	13(4.0)	3(0.9)	112 (34.9)	
	25-35	10(3.1)	17(5.3)	5(1.6)	2(0.6)	0(0)	34 (10.6)	
	Total	64(19.9)	137 (42.7)	48(15)	56 (17.4)	16(5.0)	321 (100)	

() represents percentage and *** represents significance at 1%

Summary

Based on the results, we can make several generalizations. Here are some key points:

Generalizations about perceptions for Impacts on Livelihood

- The results indicates that demographic variables Occupation and Age likely influence how individuals living in upstream region of Ranjit Sagar Dam perceive that there has been decrease in agricultural production and changes in cropping pattern that led to Impacts on Livelihood and consequently people adopted livelihood other than farming. Almost each occupational group shows strong agreement towards decreased agricultural production with most dam employees (105 out of 125) either agreed or strongly agreed that there has been a change in cropping patterns or decreased agricultural production followed by farmers and government employees. This indicates a strong perception among these groups regarding the impact on agriculture. Occupation and Age significantly affect perception regarding shifting from Farming as livelihood to other occupations such as Job in Dam office, Business and Government jobs. On the other hand, demographic variable Education does not influence how individuals perceive the Impacts on Livelihood in upstream region during Constructional Phase of Ranjit Sagar Dam.

- Similarly, during operational phase of Ranjit Sagar Dam, perceptions regarding Impact on livelihood mainly in term of Increased employment, Rise in Income level, Business flourishment and reduction in poverty are influenced by demographic variables occupation, age except education which has insignificant effect on how people look on the Impacts on Livelihood. Another significant result is that Dam employees and People in the Age Group >50 have strong perceptions about Impact on Livelihood as these groups strongly agree that Ranjit Sagar Dam has a positive impact on livelihood post construction with increased income level and decrease in poverty mainly due to business flourishment and increase employment in upstream region. On the contrary, a significant number of farmers believed that their income level did not rise post construction of Ranjit Sagar Dam Project. The strong association suggests that individuals who are dam employees view positively the economic impact of dam whereas those coming from agricultural background have negative perception regarding economic impact of this dam.
- To address these disparities, policy interventions such as Integrated Economic Development Programs, compensation and support mechanism, Investments in infrastructure improvements that benefits both dam employees and agricultural

community, Diversified livelihood opportunities and sustainable agricultural practices can be considered by policy makers.

Generalizations regarding Impacts on Community

- In this case, the variable 'Age Group' shows a strong association with individual's perception regarding Impacts on Community during constructional Phase. Occupation and education do not influence the people's views regarding Impacts on Community. Age group > 50 has strong perception for increased conflicts in upstream region with 80(24.9%) respondents (combined agreed and strongly agreed) that there were more conflicts among the community members followed by Age group 36-50 which has also significant individuals agreeing for the same issue. Overall, the upstream community perceived that during construction the Dam has negatively impacted the community. This may have happened due to more burden on already scarce resources in the region and increased mental health issues such as stress, anxiety, fear of losing access to resources.

  It reflects that the individuals above 36 years are the ones who have witnessed how the community faced challenges during the dam building. Timely interventions such as Inclusive participation of locals and to incorporate their local customs and values in policy framing might have enhanced acceptance of the project which would have led to conflict mitigation and improved resilience and over all well-being of community.
- In case of respondent's perceptions for Impacts on Community during operational phase of dam, again occupation and age have strong influence. Almost all occupational groups show disagreement /strong disagreement for access to sand mining and fishing which specifies that different groups are aware about the environmental, economic degradation of these resources after the construction of dam. However, a specific segment of Dam employees i.e., about 11.2% of them either agree or strongly agree for access to sand mining and similar number of them i.e., about 12% (combined agree and strongly agree) for access to fishing. This indicates that dam employees have direct advantage of accessing these resources which are not available to other occupational groups.

- These perceptions are significantly shaped by Age factor also. Almost all Age groups exhibit a consistent disagreement or strong disagreement regarding Access to Sand Mining and Fishing. Although, a significant number of individuals (10.9%) in Age group > 50 also agreed/strongly agreed for access to sand mining and fishing during operational phase of dam. This divergence from the general perception indicates that older individuals perceive potential benefits such as economic gain or improved livelihood from these activities.
- As occupation and age significantly shape attitudes towards resource access and management, these disparities in perceptions among Occupational and Age groups points out the complex dynamics of different stakeholder's opinions. Thus, for more inclusive decision-making, to address concerns of different stakeholders is essential.

Generalizations Regarding Impact on Infrastructure:

- There are no significant findings regarding demographic variables and perceptions for Impacts on Infrastructure during constructional phase of dam.
- In the case of Operational Phase of dam, it was found that variables such as Occupation and age have strong and significant perceptions regarding Opening of New schools and colleges, Improved Roads and Drinking water facility.
- Occupation Factors: Almost each occupational group shows disagreement for Improvement in Roads, Water Facility and opening of schools, colleges during Operational phase of Ranjit Sagar Dam. But there is significant number of Dam employees who believed that during operational phase of dam, infrastructural facilities improved. About 9.1% of them perceived that new schools and colleges were opened, 12.8% and 17.1% dam employees believed in improved water facilities and roads, respectively. These contrasting perceptions among this occupational group indicate that either dam employees have direct access to these facilities, or they reside in dam colonies. Further, it also exhibits that other occupational groups have not received such benefits. Thus, to enhance dam acceptance among various groups it is essential for dam owners and policy makers to consider all stakeholders while providing such facilities.
- Age Factor: The results show that age may influence how individuals perceive infrastructure improvement, with older group showing a mixed responses for

improved water facilities, roads and educational infrastructure and expressing doubts about the extent of improvement in these facilities. In the case of Improvement in Road infrastructure about 20.2% strongly disagreed, 39.6% disagreed, 11.5% were neutral, 23.6% agreed, and 5.0% strongly agreed. This shows that a predominant number of individuals remain doubtful about improvement of Infrastructural facilities during operational phase of Ranjit Sagar Dam, albeit among older individuals, there is some acknowledgement of infrastructural improvement. Thus, to foster greater satisfaction among community, it is necessary to address these perceptions.

For the most part, The Ranjit Sagar Dam construction is perceived differently by various Occupational groups. Dam Employees generally believed that there are more positive impacts on Livelihood, Infrastructure and Community in Upstream region during Operational Phase of Ranjit Sagar Dam. Contrastingly, other occupational groups such as farmers and people from business background believe that there are more negative impacts on Livelihood, Infrastructure and community in Upstream of Ranjit Sagar dam both during operational as well as constructional phase. It shows that the acceptance or satisfaction level about a dam is significantly influenced by employment opportunities given to the affected people by dam authorities. Thus, to lessen the disparities of perceptions, to make dam more acceptable and to reduce conflicts among different stakeholders, it is prerequisite that the opportunities or facilities which are provided to dam employees are also extended to people from other occupational background ensuring equal distribution of benefits and mitigating the cause of conflicts among various demographic groups.

The results indicate that occupation and age are significantly associated with respondents' agreement on livelihood, community and infrastructure whereas education is not. This suggests that livelihood perceptions are shaped more by respondents' current economic engagement and life-cycle position than by formal educational attainment. In the study context, education does not necessarily translate into improved employment or livelihood security, which may explain the absence of a statistically significant association.

CHAPTER 5

SOCIO-ECONOMIC IMPACTS INDUCED BY RANJIT SAGAR DAM IN DOWNSTREAM REGION

With an emphasis on both the construction and operating stages, this chapter offers a thorough statistical analysis of the views and opinions of various stakeholders regarding the socioeconomic effects connected to the construction of the Ranjit Sagar dam in the downstream area. The analysis uses the Matrix Framework to arrange the socio-economic consequences into three main themes: consequences on Livelihood, Infrastructure, and Community (Kirchherr & Charles, 2016) (Figure 5.1). There are numerous sub-components within each of these broad themes that describe the particular impacts that diverse groups have encountered.

The chapter also looks at the relationship between the socioeconomic factors that were found and a number of demographic characteristics, such as occupation, age, and education, in order to better understand the dynamics at work. This is accomplished by the use of the Chi-Square Test, a reliable statistical technique that enables the investigation of relationships between categorical variables, in hypothesis testing.

The chapter is structured with a number of major sections and related sub-sections, all of which are intended to explain the findings in an understandable and methodical manner. In order to ensure a full grasp of stakeholder viewpoints and the wider ramifications for the community, these sections seek to clarify the intricate relationship between dam development and its socioeconomic effects.

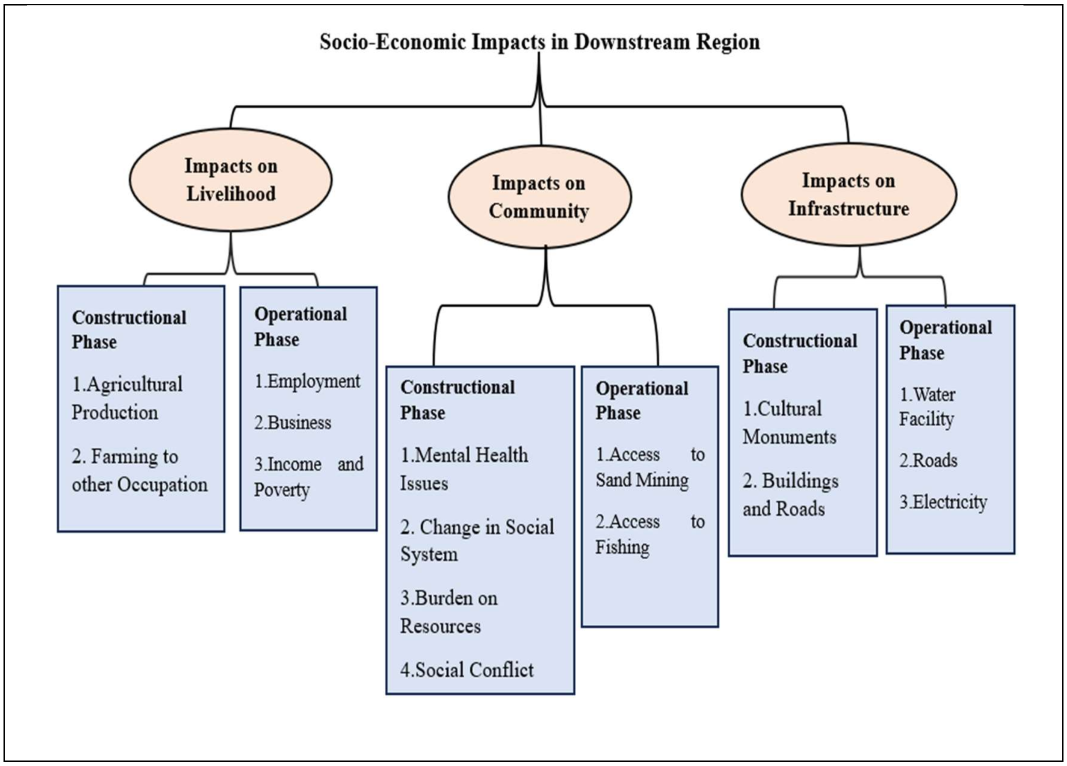
Thus, this chapter has following main sections and sub-sections:

5.1 Analysis of Socio-Economic Impacts in Downstream region of Ranjit Sagar dam during Constructional Phase.

5.2 Analysis of Socio-Economic Impacts in Downstream region of Ranjit Sagar Dam during Operational Phase.

Figure 5.1

Socio-Economic Impacts: Main Themes and Sub-components



5.1 Analysis of Socio-Economic Impacts in Downstream region of Ranjit Sagar Dam during Constructional Phase

This section deals with an analysis of three major components i.e. Impacts on Livelihood, Impact on Infrastructure and Impacts on Community. To assess the association of these components, the hypotheses testing has been done between their sub-components and demographic variables such as Occupation, Age and Education.

5.1.1 Association Between Demographic Variables (Occupation, Age and Education) and Perception for Impact on Livelihood

5.1.1.1 Association between Occupation and Impact on Livelihood

From Table 5.1 to 5.5 below, it is possible to analyze the association between Occupation and Impact on Livelihood.

Observation: Table 5.1 depicts that most of the respondents (mainly farmers) agree (48.8%) or strongly agree (7.2%) that Ranjit Sagar Dam construction led to change in cropping pattern and decreased agricultural production in upstream region. To check the association between occupation and level of agreement on Changed cropping pattern and decreased agricultural production, we used Chi-square Test. From analysis, the chi-square value for 16 d. f. (degree of freedom) and p-value (.000) was found to be 53.14 which is significant at 1%. Thus, the hypothesis stands validated proving that there exists statistically significant association between occupation and changed cropping pattern leading to decreased agricultural production and its impact on farming as livelihood.

Observation: Table 5.2 depicts that 18.4% respondents agree and 6.3% of them strongly agreed that they practiced a shift from farming to labor for earning their livelihood during construction of Ranjit Sagar Dam. The research question being investigated is whether there is a significant relationship between the occupation and adopting labour as livelihood during dam construction. To investigate, we used Chi-square Test and it is clear from the analysis (Table 5.2) that Chi- square value for 16 d. f. (degree of freedom) and p-value (.000) is 109.397 which has significance level at 1%, showing that the relationship between occupation and shift of livelihood from farming to labour during construction of Ranjit Sagar dam is statistically significant.

Observation: The data given in the Table 5.3, portrays the level of agreement or disagreement on shift of livelihood from farming to business during dam construction. About 22 (10.7%) respondents strongly disagree and 138(67.3%) disagree for adopting business as livelihood. 34 (16.6%) respondents have neutral views about this question and only 11(5.4%) respondents agreed for adopting business as livelihood. Further, to check the association, we applied Chi-square test on the data and analysis shows that the Chi-square value for 12 d. f. (degree of freedom) and p-value (.002) is 31.05 which is significant at 1%. Hence, it indicates that the relationship between occupation and adopting business as livelihood is statistically significant.

Table no. 5.1

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Changed Cropping Pattern/ Decreased Agricultural Production						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	3 (14.0%)	25 (12.1%)	23 (11.1%)	16 (7.7%)	2 (1.0%)	69 (33.3%)	53.14***
	Farmer	1 (0.5%)	5 (2.4%)	13 (6.3%)	40 (19.3%)	10 (4.8%)	69 (33.3%)	
	Business	0 (0.0%)	4 (1.9%)	6 (2.9%)	16 (7.7%)	0 (0.0%)	26 (12.6%)	
	Government Job	0 (0.0%)	2 (1.0%)	2 (1.0%)	16 (7.7%)	1 (0.5%)	21 (10.1%)	
	Others	0 (0.0%)	1 (0.5%)	6 (2.9%)	13 (6.3%)	2 (1.0%)	22 (10.6%)	
	Total	4 (1.9%)	37 (17.9%)	50 (24.2%)	101 (48.8%)	15 (7.2%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: The data depicted in Table 5.4 illustrates the level of agreement or disagreement on shift of livelihood from practicing farming to Dam employee. About 41(20.0%) respondents strongly agreed for a shift in livelihood from farming to have a job in Ranjit Sagar dam offices followed by 30(14.6%) respondents who agreed for the same. On the other hand, about 42 (20.5%) and 73 (35.6%) respondents strongly disagreed and disagree for the same. To check the association between occupation and getting a job in dam office, we applied Chi-Square test. The result of the test as shown in the Table 5.4 indicates that the value of Chi-square for 16 d. f. (degree of freedom) and p-value (.000) is 206.94 having significance at 1%. Thus, hypothesis stands validated. We conclude that there exists a significant relationship between occupation and getting employed in dam office during dam construction.

Table 5.2

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Farming to Labor						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	19 (9.2%)	41 (19.8%)	8 (3.9%)	1 (0.5%)	0 (0.0%)	69 (33.3%)	109.39 ***
	Farmer	2 (1.0%)	17 (8.2%)	13 (6.3%)	27 (13.0%)	10 (4.8%)	69 (33.3%)	
	Business	0 (0.0%)	11 (5.3%)	13 (6.3%)	2 (1.0%)	0 (0.0%)	26 (12.6%)	
	Government Job	1 (0.5%)	12 (5.8%)	8 (3.9%)	0 (0.0%)	0 (0.0%)	21 (10.1%)	
	Others	0 (0.0%)	9 (4.3%)	2 (1.0%)	8 (3.9%)	3 (1.4%)	22 (10.6%)	
	Total	22 (10.6%)	90 (43.5%)	44 (21.3%)	38 (18.4%)	13 (6.3%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: According to the Table no.5.5, the level of agreement or disagreement shows that majority of the respondents i.e. 31(15.0%) and 110(53.1%) respondents strongly disagree and disagree respectively on increase in Government jobs during Ranjit Sagar Dam construction. A small number of respondents 14(6.8%) agreed for getting government jobs during constructional phase of Ranjit Sagar dam. To test the significance, Chi-Square test was applied and results as given in Table 5.5, shows that Chi-square value for 12 d. f. (degree of freedom) and p-value (.000) is 117.53 which is significant at 1%. Thus, there exist significant relationship between occupation and shift of livelihood from farming to Govt. Job.

Table no.5.3

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood During Construction Phase

Occupation		Farming To Business					
		Strongly Disagree	Disagree	Neutral	Agree	Total	Chi-Square
Occupation	Dam Employee	5 (2.4%)	48 (23.4%)	13 (6.3%)	3 (1.5%)	69 (33.7%)	31.05***
	Farmer	11 (5.4%)	47 (22.9%)	10 (4.9%)	1 (0.5%)	69 (33.7%)	
	Business	1 (0.5%)	11 (5.4%)	9 (4.4%)	5 (2.4%)	26 (12.7%)	
	Government Job	2 (1.0%)	19 (9.3%)	0 (0.0%)	0 (0.0%)	21 (10.2%)	
	Others	3 (1.5%)	13 (6.3%)	2 (1.0%)	2 (1.0%)	20 (9.8%)	
	Total	22 (10.7%)	138 (67.3%)	34 (16.6%)	11 (5.4%)	205 (100.0%)	

() represents percentage and *** represents significance level at 1%

5.1.1.2 Association between Age and Impact on Livelihood

From the data provided in the Table 5.6 to 5.9, the association between Age Group and Impacts on Livelihood can be analyzed.

Observation: The data in Table 5.6 is depicting the level of agreement or disagreement of downstream respondents of different age groups regarding changed cropping pattern and decrease in agricultural production during constructional phase of Ranjit Sagar Dam. The data shows that majority of the respondents i.e. 101(48.8%)/ 15(7.2%) agreed/strongly agreed that there was a decrease in agricultural production during construction of Ranjit Sagar Dam. To test the significance, we applied Chi-square test and as the result shows (Table 5.6) the Chi-square value for 8 d. f. (degree of freedom) and p-value (.002) found to be 17.21 which has significance level at 5%. Therefore, there exists statistically significant relationship between Age group and changed cropping pattern and consequent agricultural production during constructional phase of Ranjit Sagar Dam.

Table no. 5.4

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Construction Phase)

Occupation		Farming to Job in Dam Office						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	0 (0.0%)	0 (0.0%)	0 (0.0%)	28 (13.7%)	41 (20.0%)	69 (33.7%)	206.94 ***
	Farmer	24 (11.7%)	35 (17.1%)	9 (4.4%)	1 (0.5%)	0 (0.0%)	69 (33.7%)	
	Business	8 (3.9%)	13 (6.3%)	3 (1.5%)	1 (0.5%)	0 (0.0%)	25 (12.2%)	
	Government Job	4 (2.0%)	11 (5.4%)	6 (2.9%)	0 (0.0%)	0 (0.0%)	21 (10.2%)	
	Others	6 (2.9%)	14 (6.8%)	1 (0.5%)	0 (0.0%)	0 (0.0%)	21 (10.2%)	
	Total	42 (20.5%)	73 (35.6%)	19 (9.3%)	30 (14.6%)	41 (20.0%)	205 (100.0%)	

() represents percentage and *** represents significance level at 1%

Table no.5.5

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impacts on Livelihood (Construction Phase)

Occupation		**Farming To Govt. Job**					
		Strongly Disagree	Disagree	Neutral	Agree	Total	Chi-Square
Occupation	Dam Employee	1 (0.5%)	28 (13.5%)	36 (17.4%)	4 (1.9%)	69 (33.3%)	117.53***
	Farmer	18 (8.7%)	41 (19.8%)	10 (4.8%)	0 (0.0%)	69 (33.3%)	
	Business	7 (3.4%)	16 (7.7%)	3 (1.4%)	0 (0.0%)	26 (12.6%)	
	Government Job	1 (0.5%)	7 (3.4%)	3 (1.4%)	10 (4.8%)	21 (10.1%)	
	Others	4 (1.9%)	18 (8.7%)	0 (0.0%)	0 (0.0%)	22 (10.6%)	
	Total	31 (15.0%)	110 (53.1%)	52 (25.1%)	14 (6.8%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: Table 5.7 depicts the level of agreement or disagreement of downstream respondents of different age groups regarding change in livelihood from farming to labor during constructional phase of Ranjit Sagar Dam. The data depicts that the respondents i.e. 38(21.3%) and 13 (18.4%) in the agreed and strongly agreed segment respectively there was a shift of livelihood from farming to labor during construction of Ranjit Sagar Dam. To test the significance, we applied Chi-square test and as the result shows (Table 5.7) that for 8 d. f. (degree of freedom) and p-value (.003), the Chi-square value found to be 23.640 which has significance level at 1%. Therefore, there exists statistically significant relationship between Age group and adopting labor as a means of livelihood during constructional phase of Ranjit Sagar Dam.

Table no. 5.6

Ranjit Sagar Dam and Downstream Region: Association Age and Impact on Livelihood (Construction Phase)

Age Group	Age	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
		Changed Cropping Pattern/ Decreased Agricultural Production						
Age Group	>50	4 (1.9%)	22 (10.6%)	23 (11.1%)	45 (21.7%)	3 (1.4%)	97 (46.9%)	17.206 **
	36-50	0 (0.0%)	9 (4.3%)	24 (11.6%)	45 (21.7%)	11 (5.3%)	89 (43.0%)	
	25-35	0 (0.0%)	6 (2.9%)	3 (1.4%)	11 (5.3%)	1 (0.5%)	21 (10.1%)	
	Total	4 (1.9%)	37 (17.9%)	50 (24.2%)	101 (48.8%)	15 (7.2%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

Observation: The data depicted in Table 5.8 illustrates the level of agreement or disagreement on shift of livelihood from practicing farming to Dam employee. About 41(20.0%) respondents strongly agreed for a shift in livelihood from farming to have a job in Ranjit Sagar dam offices followed by 30(14.6%) respondents who agreed for the same. On the other hand, about 42(20.5%) and 73(35.6%) respondents strongly disagreed and disagree for the same. To check the association between Age group and getting a job in dam office, we applied Chi-Square test. The result of the test as shown in the Table 5.8 indicates that the Chi-square value for 8 degrees of freedom and p-value (.000) is 38.058 which has significance level at 1%. Thus, there exists a significant relationship between Age group and getting employed in dam office during dam construction.

Observation: According to the Table no.5.9, the responses on level of agreement or disagreement shows that majority of the respondents i.e. 31(15.0%) and 110(53.1%)

either strongly disagree or disagree respectively on increase in Government jobs during Ranjit Sagar Dam construction. A small number of respondents 14(6.8%) agreed for getting government jobs during constructional phase of Ranjit Sagar dam. To test the significance, Chi-Square test was applied and results as given in Table 5.9, shows that Chi-square value for 6 degrees of freedom and p-value (.025) is 14.40 which is significant at 5% level. Thus, there exists statistically significant relationship between Age group and shift of livelihood from farming to Govt. Job.

Table no. 5.7

Ranjit Sagar Dam and Downstream Region: Association Age and Impact on Livelihood (Construction Phase)

	Age	Farming to Labor						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	14 (6.8%)	52 (25.1%)	20 (9.7%)	8 (3.9%)	3 (1.4%)	97 (46.9%)	23.64***
	36-50	8 (3.9%)	30 (14.5%)	21 (10.1%)	23 (11.1%)	7 (3.4%)	89 (43.0%)	
	25-35	0 (0.0%)	8 (3.9%)	3 (1.4%)	7 (3.4%)	3 (1.4%)	21 (10.1%)	
	Total	22 (10.6%)	90 (43.5%)	44 (21.3%)	38 (21.3%)	13 (18.4%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

5.1.1.3 Association between Occupation and Impact on Community

Observation: Table 5.10 portrays the description about level of agreement or disagreement for increase in mental health issues during dam constructional phase. According to the data given in the table, most of the respondents (77 or 37.2%) have neutral views followed by 82(39.6%) respondents (mainly farmers) who agree that mental health issues increased among downstream people during construction of Ranjit

Sagar Dam. On the contrary, only 37(17%) respondents (mainly dam employees) express disagreement regarding the increased mental health issues. We applied for the Chi-Square test to check if there is a significant relationship between Occupation and Increased Mental Health Issues. Result shows (Table 5.10) that the Chi-Square value for 16 degrees of freedom and p-value (.000) is 83.002 which is significant at 1%. Therefore, the association between occupation and Increased Mental Health issues is statistically significant.

Table no. 5.8

Ranjit Sagar Dam and Downstream Region: Association Age and Impact on Livelihood (Construction Phase)

	Age	Farming To Job in Dam Office						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	9 (4.4%)	26 (12.7%)	9 (4.4%)	22 (10.7%)	30 (14.6%)	96 (46.8%)	38.058 ***
	36-50	24 (11.7%)	40 (19.5%)	9 (4.4%)	7 (3.4%)	9 (4.4%)	89 (43.4%)	
	25-35	9 (4.4%)	7 (3.4%)	1 (0.5%)	1 (0.5%)	2 (1.0%)	20 (9.8%)	
	Total	42 (20.5%)	73 (35.6%)	19 (9.3%)	30 (14.6%)	41 (20.0%)	205 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: Table 5.11 portrays the description about responses on level of agreement or disagreement for increase burden on resources categorized as occupational groups. According to the data given in the table, most of the respondents (106 or 51.2%) have acknowledged that burden on resources increased during constructional phase of dam followed by 73(35.3%) respondents who are skeptical that there was pressure on resources in downstream region during construction of Ranjit Sagar Dam. We applied for the Chi-Square test to check if there is significant relationship between Occupation and perceptions regarding Increased burden on resources. Result shows (Table 5.11) that the Chi-Square value for 16 degrees of freedom and p-value (.002) is 37.393 which is significant at 1%. Therefore, individual's opinions regarding burden on resources are significantly influenced by occupation.

Table no. 5.9

Ranjit Sagar Dam and Downstream Region: Association Age and Impact on Livelihood (Construction Phase)

	Age	**Farming to Govt. Job**					
		Strongly Disagree	Disagree	Neutral	Agree	Total	Chi-Square
Age Group	>50	8 (3.9%)	49 (23.7%)	29 (14.0%)	11 (5.3%)	97 (46.9%)	14.40**
	36-50	18 (8.7%)	51 (24.6%)	17 (8.2%)	3 (1.4%)	89 (43.0%)	
	25-35	5 (2.4%)	10 (4.8%)	6 (2.9%)	0 (0.0%)	21 (10.1%)	
	Total	31 (15.0%)	110 (53.1%)	52 (25.1%)	14 (6.8%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

Observation: Table 5.12 illustrates responses of different occupation groups on level of agreement or disagreement for increased conflicts. About (91or 44%) respondents (mostly farmers) show agreement that conflicts among community members increased during constructional phase of dam followed by 65(31.4%) respondents are in doubt whether the social conflict increased or not in downstream region during construction of Ranjit Sagar Dam. But there are a significant number of respondents (17%) (mostly dam employees) who also disapprove of any increased social conflicts. To assess if there is significant relationship between Occupation and perceptions regarding Increased social conflicts, we used Chi-square Test. Analysis shows that the Chi-Square value for 16 degrees of freedom and p-value (.000) is 47.45 which is significant at 1%. Therefore, difference in individual's opinions regarding Increased conflicts are significantly depends on occupation.

Table no. 5.10

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Community (Construction Phase)

		Increased Mental Health Issues						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	4 (1.9%)	23 (11.1%)	40 (19.3%)	2 (1.0%)	0 (0.0%)	69 (33.3 %)	83.002 ***
	Farmer	1 (0.5%)	4 (1.9%)	18 (8.7%)	41 (19.8%)	5 (2.4%)	69 (33.3 %)	
	Business	0 (0.0%)	2 (1.0%)	8 (3.9%)	15 (7.2%)	1 (0.5%)	26 (12.6 %)	
	Government Job	0 (0.0%)	7 (3.4%)	4 (1.9%)	10 (4.8%)	0 (0.0%)	21 (10.1 %)	
	Others	0 (0.0%)	1 (0.5%)	7 (3.4%)	14 (6.8%)	0 (0.0%)	22 (10.6 %)	
	Total	5 (2.4%)	37 (17.9%)	77 (37.2%)	82 (39.6%)	6 (2.9%)	207 (100. 0%)	

() represents percentage and *** represents significance level at 1%

5.1.1.4 Association between Age and Impact on Community

Observation: Table 5.13 depicts responses of various Age groups about level of agreement or disagreement for increase in mental health issues during dam constructional phase. According to the data given in the table, most of the respondents (82 or 39.6%) (mostly 36-50 years old) agree with assertion that mental health issues increased during construction phase followed by 77(37.2%) respondents (mostly >50 years) who were neutral to this assertion during construction of Ranjit Sagar Dam. Although a significant number of respondents mostly in the age group>50 years denied about increased mental health issues. We applied for the Chi-Square test to check if there is significant relationship between Occupation and Increased mental health issues. Result shows (Table 5.13) that the Chi-Square value for 8 degrees of freedom and p-value (.000) is 30.953 which is significant at 1%. Therefore, the association is statistically significant and we can say that Age has significant influence on individual's attitude towards increase in mental health issues.

Table no.5.11

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Community (Construction Phase)

		Burden on Resources						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	1 (0.5%)	15 (7.2%)	25 (12.1%)	26 (12.6%)	2 (1.0%)	69 (33.3%)	37.393 ***
	Farmer	0 (0.0%)	1 (0.5%)	22 (10.6%)	44 (21.3%)	2 (1.0%)	69 (33.3%)	
	Business	0 (0.0%)	2 (1.0%)	13 (6.3%)	11 (5.3%)	0 (0.0%)	26 (12.6%)	
	Government Job	0 (0.0%)	0 (0.0%)	3 (1.4%)	18 (8.7%)	0 (0.0%)	21 (10.1%)	
	Others	0 (0.0%)	4 (1.9%)	10 (4.8%)	7 (3.4%)	1 (0.5%)	22 (10.6%)	
	Total	1 (0.5%)	22 (10.6%)	73 (35.3%)	106 (51.2%)	5 (2.4%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

Table no. 5.12

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Community (Construction Phase)

	Occupation	Increased Conflicts						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	1 (0.5%)	25 (12.1%)	13 (6.3%)	30 (14.5%)	0 (0.0%)	69 (33.3%)	47.45***
	Farmer	1 (0.5%)	3 (1.4%)	24 (11.6%)	36 (17.4%)	5 (2.4%)	69 (33.3%)	
	Business	0 (0.0%)	3 (1.4%)	13 (6.3%)	9 (4.3%)	1 (0.5%)	26 (12.6%)	
	Government Job	0 (0.0%)	2 (1.0%)	7 (3.4%)	7 (3.4%)	5 (2.4%)	21 (10.1%)	
	Others	0 (0.0%)	3 (1.4%)	8 (3.9%)	9 (4.3%)	2 (1.0%)	22 (10.6%)	
	Total	2 (1.0%)	36 (17.4%)	65 (31.4%)	91 (44.0%)	13 (6.3%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: Table 5.14 depicts responses of various Age groups about level of agreement or disagreement for changed social system during dam's constructional phase. According to the data given in the table, most of the respondents (80 or 38.6%) (mostly above 50 years old) neither agree nor disagree with assertion that mental social system changed during construction phase followed by 72(34.8%) respondents (mostly 36-50 years old) show admit that there was change in social system downstream region during construction of Ranjit Sagar Dam. Although a significant number of respondents mostly in the age group>50 years show disagreement about changed social system. We applied for the Chi-Square test to check the if there is significant relationship between

Occupation and Changed social system. From analysis the Chi-Square value for 8 degrees of freedom and p-value (.024) is 17.683 which is significant at 5%. Therefore, the association between Age group and changed social system is statistically significant and we can say that diverse perceptions of individuals regarding Changed social system are significantly related to Age factor in downstream region of Ranjit Sagar Dam.

Table no. 5.13

Ranjit Sagar Dam and Downstream Region: Association between Age and Impact on Community (Construction Phase)

Age		Increased Mental Health Issues						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	5 (2.4%)	26 (12.6%)	41 (19.8%)	25 (12.1%)	0 (0.0%)	97 (46.9%)	30.953***
	36-50	0 (0.0%)	7 (3.4%)	29 (14.0%)	48 (23.2%)	5 (2.4%)	89 (43.0%)	
	25-35	0 (0.0%)	4 (1.9%)	7 (3.4%)	9 (4.3%)	1 (0.5%)	21 ()	
	Total	5 (2.4%)	37 (17.9%)	77 (37.2%)	82 (39.6%)	6 (2.9%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

5.2 Analysis of Impacts on Livelihood, Infrastructure and Community during Operational Phase of Ranjit Sagar Dam Project

In this section, we analyse how various categorical variables—specifically Occupation, Age, and Education Level—interact with and influence the impacts on Livelihood, Infrastructure, and Community during the operational phase of a project.

Table no. 5.14

Ranjit Sagar Dam and Downstream Region: Association between Age and Impact on Community (Construction Phase)

Age		Change in Social System						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	3 (1.4%)	28 (13.5%)	41 (19.8%)	25 (12.1%)	0 (0.0%)	97 (46.9%)	17.68**
	36-50	1 (0.5%)	13 (6.3%)	30 (14.5%)	42 (20.3%)	3 (1.4%)	89 (43.0%)	
	25-35	1 (0.5%)	6 (2.9%)	9 (4.3%)	5 (2.4%)	0 (0.0%)	21 (10.1%)	
	Total	5 (2.4%)	47 (22.7%)	80 (38.6%)	72 (34.8%)	3 (1.4%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

5.2.1. Association between Demographic variables (Occupation, Age and Education) and Perceptions regarding Impacts on Livelihood

5.2.1.1 Association between Occupation and Impacts on Livelihood

First of all, we have categorized Livelihood under different components namely Employment, Business flourishment, Income and Reduction in Poverty. To analyze the Impacts on Livelihood and its relationship with categorical variable 'Occupation', we have applied Chi-square test.

Observation: The Table 5.15, outlines the level of agreement or disagreement of downstream respondents regarding Increase in Employment during operational phase. The data specified here shows that almost equal number of respondents either disagree or were neutral (mostly farmers). About 25.7% respondents (mostly dam employees) agree that there was increase in employment during operational phase of Ranjit Sagar

Dam. On the other hand, 32.7% respondents (mainly farmers) disagree for the same. To verify the significance, we applied Chi-Square test and result (Table no.5.15) shows that its value for 16 degrees of freedom and p-value (.000) is 125.89 which is significant at 1%. For that reason, it is concluded that association between Occupation and increase in Employment during operational phase is statistically significant and it indicates that individual's perceptions are influenced by occupation.

Table no. 5.15

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Operational Phase)

		Increased Employment in Your Area						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	5 (2.4%)	4 (1.9%)	5 (2.4%)	42 (20.4%)	13 (6.3%)	69 (33.5%)	125.89 ***
	Farmer	3 (1.5%)	34 (16.5%)	25 (12.1%)	7 (3.4%)	0 (0.0%)	69 (33.5%)	
	Business	1 (0.5%)	14 (6.8%)	10 (4.9%)	1 (0.5%)	0 (0.0%)	26 (12.6%)	
	Government Job	1 (0.5%)	7 (3.4%)	13 (6.3%)	0 (0.0%)	0 (0.0%)	21 (10.2%)	
	Others	0 (0.0%)	8 (3.9%)	10 (4.9%)	3 (1.5%)	0 (0.0%)	21 (10.2%)	
	Total	10 (4.9%)	67 (32.5%)	63 (30.6%)	53 (25.7%)	13 (6.3%)	206 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: The data in Table no.5.16 represents respondent's agreement or disagreement on Rise in income level and Reduction in Poverty during operational phase of Ranjit Sagar Dam. It is clearly illustrated from the below given Table 5.16 that the respondents who were either neutral or agreed to the above statement were almost same (52 or 25.2%) and (55 or 26.7%) respectively. The respondents (most of them are farmers) who disagreed for the above-mentioned component is (83 or 40.3%). To check whether there is an association between the occupation and the component (as mentioned in Table 5.16), we used Chi-square Test wherein its value for 16 degrees of freedom and p-value (.000) found to be 131.91 which has significance level at 1% pointing that there is significant relationship between the occupation and Rise in Income level and reduced poverty after Ranjit Sagar Dam Construction and difference in people's attitude towards rise in income level and reduced poverty is significantly influenced by occupation.

Table no. 5.16

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Operational Phase)

		Increased Income and Reduced Poverty						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	1 (0.5%)	7 (3.4%)	3 (1.5%)	43 (20.9%)	15 (7.3%)	69 (33.5%)	131.91 ***
	Farmer	0 (0.0%)	44 (21.4%)	18 (8.7%)	7 (3.4%)	0 (0.0%)	69 (33.5%)	
	Business	0 (0.0%)	12 (5.8%)	12 (5.8%)	2 (1.0%)	0 (0.0%)	26 (12.6%)	
	Government Job	0 (0.0%)	12 (5.8%)	9 (4.4%)	0 (0.0%)	0 (0.0%)	21 (10.2%)	
	Others	0 (0.0%)	8 (3.9%)	10 (4.9%)	3 (1.5%)	0 (0.0%)	21 (10.2%)	
	Total	1 (0.5%)	83 (40.3%)	52 (25.2%)	55 (26.7%)	15 (7.3%)	206 (100.0%)	

() represents percentage and *** represents significance level at 1%

Observation: According to the data set forth in the Table no. 5.17, respondent's level of agreement or disagreement towards burgeoning business or market after dam construction is described. Majority of the respondents (mainly farmers) i.e. 104(50.2%) show disagreement for any growth of business during operational phase of Ranjit Sagar Dam. But significant number of respondents, about 91(44.0%) remained neutral. We used Chi-square test to verify the significant relationship between occupation and business flourishment. Chi-square value for 16 d. f. (degree of freedom) and p-value .02 is 29.696 which has significance level at 5% indicating that there is significant association between Occupation and perception on business growth.

Table no. 5.17

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Operational Phase)

		Business Flourished						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	2 (1.0%)	18 (8.7%)	46 (22.2%)	3 (1.4%)	0 (0.0%)	69 (33.3%)	29.696 **
	Farmer	2 (1.0%)	43 (20.8%)	21 (10.1%)	2 (1.0%)	1 (0.5%)	69 (33.3%)	
	Business	1 (0.5%)	16 (7.7%)	8 (3.9%)	1 (0.5%)	0 (0.0%)	26 (12.6%)	
	Government Job	0 (0.0%)	13 (6.3%)	8 (3.9%)	0 (0.0%)	0 (0.0%)	21 (10.1%)	
	Others	0 (0.0%)	14 (6.8%)	8 (3.9%)	0 (0.0%)	0 (0.0%)	22 (10.6%)	
	Total	5 (2.4%)	104 (50.2%)	91 (44.0%)	6 (2.9%)	1 (0.5%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

5.2.1.2 Association between Age and Impact on Livelihood

Observation: Table no.5.18 depicts the data about downstream respondent's agreement or disagreement for Increase in employment during operational phase. An almost equal number of respondents either remained neutral i.e., 63 (30.6%) or 67(32.5%) showed disagreement for the question whereas 53(25.7%) respondents agreed that employment increased in their region after dam construction. To test the association between Age and Increased employment, the Chi-square test was applied, and results show the Chi-square value for 8 degrees of freedom and p-value (.01) is 18.28 which is significant at 5%. Hence, Age group and perceptions regarding Increased employment in downstream region are significantly associated with each other.

Table no. 5.18

Ranjit Sagar Dam and Downstream Region: Association between Age and Impact on Livelihood (Operational Phase)

Age		Increased Employment in Your Area						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	5 (2.4%)	24 (11.7%)	24 (11.7%)	34 (16.5%)	10 (4.9%)	97 (47.1%)	18.28**
	36-50	4 (1.9%)	33 (16.0%)	34 (16.5%)	15 (7.3%)	2 (1.0%)	88 (42.7%)	
	25-35	1 (0.5%)	10 (4.9%)	5 (2.4%)	4 (1.9%)	1 (0.5%)	21 (10.2%)	
	Total	10 (4.9%)	67 (32.5%)	63 (30.6%)	53 (25.7%)	13 (6.3%)	206 (100.0%)	

() represents percentage and ** represents significance level at 5%

5.2.1.3 Association between Occupation and Impact on Infrastructure

Observation: Table 5.19 shows the level of agreement for Improvement in roads during operational phase of Ranjit Sagar dam. To assess the relationship between Occupation and Impact on Roads improvement, we used Chi-Square Test. The analysis shows that for 16 degrees of chi-square and p-value (.000) is 55.67 which is significant at 1%. Thus, the hypothesis stands validated. Thus, there exists a significant association between Occupation and level of agreement on Improved roads after the construction of Ranjit Sagar Dam. The data in Table 5.19 also depicts that majority of the respondents believed that there is improvement in road infrastructure in downstream region after the construction of dam and as this is statistically proved, thus it is generalized that Ranjit Sagar Dam contribute considerably towards the road improvement in downstream region. Although, a certain number of individuals i.e., 22% (mostly farmers) disapprove of the road improvement in the region after Ranjit Sagar dam construction.

Observation: Table 5.20 shows the level of agreement for Improvement in Drinking Water Facility in downstream region during operational phase of Ranjit Sagar dam. To assess the relationship between Occupation and Impact on Drinking water facility improvement, we used Chi-Square Test. The analysis shows that for 12 degrees of chi-square and p-value (.01) is 25.28 which is significant at 5%. Thus, the hypothesis stands validated. Further as the Table 5.20 illustrates that majority of the respondents perceived that Drinking water facility did not get better in downstream region after the construction of Ranjit Sagar Dam and same is statistically validated, thus it can be asserted that there was no amelioration in water facilities in downstream region due to Ranjit Sagar Dam construction.

Observation: Table 5.21 shows the level of agreement for Opening of New Schools and Colleges during operational phase of Ranjit Sagar dam. Most of the respondents (92 or 44.4%) disagreed about opening of new schools and colleges in the downstream region after the dam construction. To assess the relationship between Occupation and Impact on opening of new schools and colleges, we used Chi-Square Test. The analysis shows that for 12 degrees of chi-square and p-value (.000) is 46.465 which is significant at 1%. Thus, the hypothesis stands validated. Hence it is affirmed that in the downstream region the educational infrastructure did not get upgraded after the construction of Ranjit Sagar Dam.

Table 5.19

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Infrastructure (Operational Phase)

Occupation		Improved Roads						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	0 (0.0%)	7 (3.4%)	3 (1.4%)	27 (13.0%)	32 (15.5%)	69 (33.3%)	55.67***
	Farmer	3 (1.4%)	21 (10.1%)	17 (8.2%)	19 (9.2%)	9 (4.3%)	69 (33.3%)	
	Business	0 (0.0%)	4 (1.9%)	10 (4.8%)	9 (4.3%)	3 (1.4%)	26 (12.6%)	
	Government Job	2 (1.0%)	6 (2.9%)	6 (2.9%)	4 (1.9%)	3 (1.4%)	21 (10.1%)	
	Others	1 (0.5%)	8 (3.9%)	3 (1.4%)	7 (3.4%)	3 (1.4%)	22 (10.6%)	
	Total	6 (2.9%)	46 (22.2%)	39 (18.8%)	66 (31.9%)	50 (24.2%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

5.2.3 Association between demographic variables (Occupation, Age and Education) and perceptions regarding Impacts on Community

5.2.3.1 Association between Occupation and Impact on Community

Observation: Table 5.22 shows the level of agreement for access to fishing during operational phase of Ranjit Sagar dam. There is a total of 207 respondents across various occupations, with a majority indicating disagreement on having access to fishing (43.5% disagree and 39.1% strongly disagree) followed by 17.4% respondents who are sceptical about the access to resources. To assess the relationship between Occupation and Impact on access for Fishing, we used Chi-Square Test. The analysis shows that for 8 degrees of freedom and p-value (.02), the value of Chi-square is 17.90 which is significant at 5%. Thus, the hypothesis stands validated. Thus, it can be asserted that people's perception on access to resources is strongly influenced by occupation.

Table 5.20

Ranjit Sagar Dam: Association between Occupation and Improved Drinking Water

	Occupation	**Improved Drinking Water Facility**					
		Strongly Disagree	Disagree	Neutral	Agree	Total	Chi-Square
Occupation	Dam Employee	12 (5.8%)	30 (14.5%)	25 (12.1%)	2 (1.0%)	69 (33.3%)	25.28**
	Farmer	22 (10.6%)	31 (15.0%)	16 (7.7%)	0 (0.0%)	69 (33.3%)	
	Business	5 (2.4%)	13 (6.3%)	8 (3.9%)	0 (0.0%)	26 (12.6%)	
	Government Job	11 (5.3%)	10 (4.8%)	0 (0.0%)	0 (0.0%)	21 (10.1%)	
	Others	9 (4.3%)	11 (5.3%)	2 (1.0%)	0 (0.0%)	22 (10.6%)	
	Total	59 (28.5%)	95 (45.9%)	51 (24.6%)	2 (1.0%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

Table no. 5.21

Ranjit Sagar dam: Association of Occupation and Impacts on Infrastructure

Occupation		New Schools and Colleges: Strongly Disagree	Disagree	Neutral	Agree	Total	Chi-Square
Occupation	Dam Employee	1 (0.5%)	17 (8.2%)	34 (16.4%)	17 (8.2%)	69 (33.3%)	46.47***
	Farmer	4 (1.9%)	36 (17.4%)	28 (13.5%)	1 (0.5%)	69 (33.3%)	
	Business	0 (0.0%)	13 (6.3%)	13 (6.3%)	0 (0.0%)	26 (12.6%)	
	Government Job	1 (0.5%)	13 (6.3%)	7 (3.4%)	0 (0.0%)	21 (10.1%)	
	Others	2 (1.0%)	13 (6.3%)	7 (3.4%)	0 (0.0%)	22 (10.6%)	
	Total	8 (3.9%)	92 (44.4%)	89 (43.0%)	18 (8.7%)	207 (100.0%)	

() represents percentage and *** represents significance level at 1%

The results show that occupation and age are significantly related with respondents' agreement on livelihood, community and infrastructure whereas education is not. The findings suggest that livelihood perceptions are shaped primarily by current economic involvement and life-cycle stage rather than formal educational level. In this context, education does not necessarily result in improved employment or livelihood security, possibly explaining the non-significant association.

Table 5.22

Ranjit Sagar Dam and Downstream Region: Association between Occupation and Impact on Livelihood (Operational Phase)

Occupation		Access To Fishing				
		Strongly Disagree	Disagree	Neutral	Total	Chi-Square
Occupation	Dam Employee	16 (7.7%)	34 (16.4%)	19 (9.2%)	69 (33.3%)	17.90**
	Farmer	37 (17.9%)	24 (11.6%)	8 (3.9%)	69 (33.3%)	
	Business	13 (6.3%)	10 (4.8%)	3 (1.4%)	26 (12.6%)	
	Government Job	7 (3.4%)	11 (5.3%)	3 (1.4%)	21 (10.1%)	
	Others	8 (3.9%)	11 (5.3%)	3 (1.4%)	22 (10.6%)	
	Total	81 (39.1%)	90 (43.5%)	36 (17.4%)	207 (100.0%)	

() represents percentage and ** represents significance level at 5%

Summary

Based on the results, we can make several generalizations. Here are some key points:

Generalizations about perceptions for Impacts on Livelihood

- The results indicates that demographic variables Occupation and Age likely influence how individuals living in downstream region of Ranjit Sagar Dam perceive that there has been decrease in agricultural production and changes in cropping pattern that led to Impacts on Livelihood and therefore people adopted livelihood other than farming. Many farmers (40 out of 69) either agreed or strongly agreed that there has been a change in cropping patterns or decreased agricultural production. This indicates a strong perception among this group regarding the impact on agriculture. Occupation and Age significantly affect perception regarding shifting from Farming as livelihood to other occupations such as Job in Dam office, Business and Government jobs. On the other hand, demographic variable Education does not influence how individuals perceive the Impacts on Livelihood in downstream region during Constructional Phase of Ranjit Sagar Dam.

- Similarly, during operational phase of Ranjit Sagar Dam, perceptions regarding Impact on livelihood mainly in term of Increased employment, Rise in Income level, Business flourishment and reduction in poverty are influenced by demographic variables occupation, age except education which has insignificant effect on how people look on the Impacts on Livelihood. Another significant result is that Dam employees (43 or 20.9%) and People in the Age Group >50 have strong perceptions about Impact on Livelihood as these groups strongly agree that Ranjit Sagar Dam has a positive impact on livelihood post construction with increased income level and decrease in poverty mainly due to increased employment in upstream region. On the contrary, a significant number of farmers (44 or 21.5%) of total respondents believed that their income level did not rise post construction of Ranjit Sagar Dam Project. The strong association suggests that individuals who are dam employees view positively the economic impact of dam whereas those coming from agricultural background have negative perception regarding economic impact of this dam. In case of business flourishing, individuals from all occupations perceived that there were no positive impacts on the business sector during operational phase of dam.
- To address these disparities, policy interventions such as Integrated Economic Development Programs, compensation and support mechanism, Investments in infrastructure improvements that benefits both dam employees and agricultural community, Diversified livelihood opportunities and sustainable agricultural practices can be considered by policy makers.

Generalizations for Impacts on Community

- In this case, the variable occupation and ‘Age Group’ show a strong association with individual’s perception regarding Impacts on Community during constructional Phase. Education does not influence the people's views regarding Impacts on Community. Group of respondents from agricultural background (41 or 19.8%) and those in the age group 36-50 years (43 or 23.2%) have strong perceptions for increased mental health issues among downstream community followed by business owners (7.2%) and Age group >50 (12.1%) which has also significant individuals agreeing for the same issue. Overall, the downstream community perceived that during construction the Dam has negatively impacted the community. This may have happened due to more burden on already scarce resources in the region and increased conflicts and changed social system as significantly viewed by the individuals with different occupations. Notably, a specific number of dam employees have believed that Ranjit Sagar Dam did not impact community adversely.

It reflects that the individuals above 36 years are the ones who have witnessed how the community faced challenges during the dam building. Timely interventions such as Inclusive participation of locals and to incorporate their local customs and values in policy framing might have enhanced acceptance of the project which would have led to conflict mitigation and improved resilience and over all well-being of community.

- In case of respondent's perceptions for Impacts on Community during operational phase of dam, only occupation has strong influence. Almost all occupational groups (mainly dam employees (16.4%) followed by farmers (11.6%)) show disagreement /strong disagreement for access to fishing which specifies that different groups are aware about the environmental, economic degradation of these resources after the construction of dam. Similarly, business owners and government employee outrightly express disapproval of access to fishing. However, a specific segment of Dam employees i.e., about 9.2% of them neither agree nor disagree for access to sand resources such as fishing. This indicates that dam employees have direct advantage of accessing these resources which are not available to other occupational groups. This suggests that they may not have the same awareness as others about the broader ecological consequences of the dam's operation.

- As occupation significantly shape attitudes towards resource access and management, these disparities in perceptions among Occupational groups point out the complex dynamics of different stakeholder's opinions about the degradation of local environment resources indicating that operational phase of dam may have critical economic and environmental shifts which impacts the livelihood of the community. Thus, for more inclusive decision-making, to address concerns of different stakeholders is essential.

Generalizations for Impacts on Infrastructure:

- There are no significant findings regarding demographic variables and perceptions for Impacts on Infrastructure during constructional phase of dam.
- In the case of Operational Phase of dam, it was found that demographic variable Occupation have strong and significant perceptions regarding Opening of New schools and colleges, Improved Roads and Drinking water facility.
- Occupation Factors: Almost each occupational group shows agreement for Improvement in Roads infrastructure during Operational phase of Ranjit Sagar Dam. About 60 (31.9%) and 50 (24.2%) individuals agree and strongly agree respectively showing a positive attitude regarding Improved Road facilities during operational phase. But a section of farmers (about 10.1%) believed that during operational phase of dam, road infrastructural facilities did not improve. These contrasting perceptions among this occupational group exhibit that some people from agricultural backgrounds might not get better connectivity with transport network. Thus, to enhance dam acceptance among various groups it is essential for dam owners and policy makers to consider all stakeholders while providing such facilities.
- The results show that occupation may influence how individuals perceive improvement in drinking water facility and educational infrastructure during dam's operation with all occupational groups showing outright disapproval for improved water facilities as 45.9% and 28.5% individuals disagreed and strongly disagreed, respectively. It indicates that regardless of the occupation, most respondents feel that quality or access to water facilities had not been positively impacted by the dam. This widespread disapproval highlights the

need for further investigation to analyze the quality of water facilities and access to these provisions for locals in the downstream region.

- In the case of Improvement in educational infrastructure such as opening of new schools and colleges, about 92 or 44.4% individuals show dissatisfaction for improved educational infrastructure. Also, a significant number of respondents, about 43.1% express mixed response indicating they are doubtful on the extent of improvement in educational facilities in the downstream region. This shows that a predominant number of individuals (mainly dam employees) are sceptical about improvement of Infrastructural facilities during operational phase of Ranjit Sagar Dam, albeit among dam employees, there is some acknowledgement of educational infrastructure improvement with 8.2% of them feel that dam has positively impacted the opening new schools and colleges. These diverse perceptions point out that some dam employees have the advantage or more access to educational facilities as compared to individuals from other occupations. Thus, to foster greater satisfaction among community, it is necessary to address these perceptions.

For the most part, The Ranjit Sagar Dam construction is perceived differently by various Occupational groups. Respondents generally believed that there are more negative impacts on Infrastructure (except roads) and Community in downstream region during Operational Phase of Ranjit Sagar Dam. If we talk about Impacts on livelihood, dam employees feel that after dam construction their livelihood was positively impacted with increased employment opportunities, rise in income level and reduced poverty while people from other occupations are having the different opinion, mainly farmers seem less satisfied with employment opportunities after the dam construction. Contrastingly, other occupational groups such as farmers and people from business background believe that there are more negative impacts on Livelihood, Infrastructure and community in downstream of Ranjit Sagar dam both during operational as well as constructional phase. It shows that the acceptance or satisfaction level about a dam is significantly influenced by employment opportunities given to the affected people by dam authorities. Thus, to lessen the disparities of perceptions, to make dam more acceptable and to reduce conflicts among different stakeholders, it is prerequisite that the opportunities or facilities which are provided to Dam employees are made available to other occupational groups also.

CHAPTER 6

DAM FAILURE RISKS AND DAM SAFETY MEASURES

As explained in Matrix Framework (Kirchherr & Charles, 2016) on social impacts of dams, flood control and dam failures also fall under the category of social impacts but while analysing the social impacts of large dams, flood control and dam failure risk is generally neglected by research community. To explore these components is essential because dam failure and flood control are related to dam's infrastructure and impacts of flood control and dam failures may bring changes in people's livelihood and impacts on community. To further unravel the interconnected dynamics of Infrastructure, livelihood and community we are presenting this chapter wherein we will proceed with the potential causes of dam failures in India and based upon the history of previous dam failures, the potential risks of failure to Ranjit Sagar Dam will be evaluated. Finally, to understand how different demographic groups perceive the potential failure risks to Ranjit Sagar Dam and adequacy of dam safety measures, hypothesis testing is done.

Dam Failures are the disastrous events that diminish the social, environmental, economic sustainability of dams and poses high risk to the people and property in the downstream area (Roulo & Pichuka, 2022). For instance, 200 dam failures have resulted in 8000 deaths globally (Anantha, 2015). In India, Machhu dam failure in 1979 is considered the worst (Bhaduri, 2012). In Brazil, the failure of Minas Gerrais Dam has resulted in 20 deaths and contamination of major river system (Gerlak et al. 2020). At global level, for dams constructed after 1950, the failure rate is 0.5% whereas 2.2% of dams constructed before 1950 have failed (Central Water Commission, 2018a). As stated by Agoramorthy (2012), aging is a significant issue for dam infrastructure (Figure 6.1), with around 500 dams in India being over 50 years old. Among them, 227 dams are nearly 100 years old and are still operational. Additionally, 80% of the 5,700 large dams in the country are over 25 years old (PIB Delhi, 2021). These aging dams are increasingly susceptible to the effects of climate change due to their infrastructure not meeting modern standards (Saran et al.2023). This chapter is divided into following sections to describe and evaluate the dam failure risks to Indian dams in general and to Ranjit Sagar Dam in particular.

6.1 Statistical analysis of previous dam failures in India

6.2 Potential failure risks to Ranjit Sagar Dam

6.3 Perception of People residing upstream and downstream of Ranjit Sagar Dam about flood occurrence and dam safety measures.

6.1 Statistical Analysis of previous Dam Failures in India

Several studies have been conducted to examine dam failures in India. Mohan & Kumar (2013) analysed data on earthquakes and seismic zones as potential causes of dam failures. Dhiman & Patra (2019) compiled information on Indian dam failures to develop an equation for breach parameters. Raj (2022) discussed dam safety in India and reported on dam failures in his report "Overview of Dam Safety Act-2021." Additionally, there have been a few efforts to investigate the causes of failures specifically in earth dams in India and to classify their failure modes.

In this section, data about 50 dam failure cases in India have been collected from the literature (e.g., Zhang et al. 2016a, Talukdar & Dey, 2019, Sharma & Kumar, 2013, Dhiman & Patra, 2019) and compiled. The failure information and details of the characteristics of the dams were collected. Various dam types such as earth dams, concrete dams, masonry dams, rockfill dams, and so on comprised our studied cases. Through statistical analysis a total of 39 failure cases of earth dams are utilised to study earth dam failures. Analysis have been done on the basis of dam and material types, the failure modes and causes of earth dams. Locations with potential risk are also described for a comprehensive understanding of dam failures in India.

6.1.1 Dam Failure Modes

Each component of dam structure undergoes different kind of defects as each component is made with different construction material e.g., concrete with steel is used to build spillways and core of earth dam is made of impervious material like clay. Thus, their stress holding capacity is also different (Harsha, 2019). Generally, a dam collapses when there is a defect in either main structure (Dam Body and Foundation) or parts of the appurtenant structure (Spillways, Conduit, Power plants) (Zhang et al.2016b). Table 6.1 summarizes the different modes and causes of Dam failure.

Table no. 6.1

Dam Failure: Types/Modes and Causes

Types/Modes of Dam Failure	Causes of Dam Failure
Hydrologic Failure Mode	Overtopping, erosion of surface materials, breaching due to floods
Geologic Failure Mode	It includes slope instability, wrong geotechnical designs of dam body and foundation, inadequate seepage control
Piping/Internal Erosion Failure Mode	Concentrated seepage in dam body, conduits and abutments is Piping. Internal erosion takes place at the boundary of two zones in the dam body or the contact zone between the dam body and foundation
Structural Failure Mode	A critical dam component failure due to wrong construction practice and poor maintenance
Seismic Failure Mode	Ground movement or liquefaction due to earthquakes
Human -induced Failure Mode	Improper design or maintenance, mis operation, acts of terrorism, sudden and uncontrolled opening of gates without prior warning

Source: Central water commission, 2018b

Table no. 6.2

Dam failures in India: Compiled Data of Previous Dam Failures

(Location Map of Dam Failures shown in Map 6.1)

Name	Type	Subtype	Height (m)	Year of Const.	Year of Failure	Cause of Failure	Sub cause	Reservoir capacity (MCM)
Ahraura Dam	Earth	Concrete faced	26	1953	1953	Quality Problem	-	61
Asthi	Earth	-	17.70	1883	1933	Slope failure	-	-
Anwar	Earth	-	12.5	1956	1957	Breaching	-	-
Bhimlot	Masonry	Gravity	17	1958	-	Overtopping	-	-
Chadiya	Earth	-	22.50	1926	2008	Breaching	-	-
Chandora	Earth	-	27.30	1986	1991, 2007	Breach	Crack in dam body	18.2

Chigalli	Earth	-	21	1978	2007	Breach	Crack in dam body/ improper gate functioning	8.85
Chitauni	Earth	Rockfill	-	-	1968	-	-	-
Dakhya	Earth	-	-	1953	1953	Breaching	-	-
Dantiwada	Earth	Composite Dam	60.96	1965	1973	Overtopping	Design flood	464
Dervakheda	Earth	-	-	-	1959	Breaching	-	-
Dhanibara	Earth	-	20.7	1975	1976	Overtopping	-	61
Gararda Dam	Earth	Homogeneous	31.76	2010	2012	Overtopping	Bad workmanship	44.38
Galwania	Earth	-	-	1960	1961	Breaching	-	-
Girinanda	Earth	-	12.24	1954	1955	Overtopping	Breach	-
Guddah	Earth	Homogeneous	28.30	1956	1957	Breaching	Bad workmanship	-
Gurilijore	Earth	Homogeneous	12.19	1955	2004	Piping	Quality problem	2.179
Jamunia	Earth	Homogeneous	15.40	1921	2002	Piping	Breaching	9.209
Jaswant Sagar	Earth	-	43.38	1889	2007	Piping	Breaching	40.83

Kadam	Earth	Composite	22.50	1958	1995	Overtopping	Breaching/ Inadequate spillway capacity	215.30
Kaila 1	Earth	Homogeneous	26.3	1955	1959	Quality problem	structural failures of dam body-foundation unit by sliding	14
Kaila 2	Earth	-	24.5	-	1965	Overtopping	Insufficient Spillway	-
Kedarnala	Earth	-	20	1964	1964	Piping	Quality Problem	17
Khadakwasala	Masonry	Gravity	60	1875	1961	Overtopping	-	86
Kharagpur	Earth	-	24	1961	1961	Overtopping	-	55
Kodaganar	Earth	Homogeneous	12.75	1977	1977	Breaching	Insufficient spillway and storage capacity	123
Kohodiar	Earth and Concrete	Composite	36	1963	1983	-	-	41
Kundli	Masonry	Gravity	45	1924	1925	Quality problem	-	-

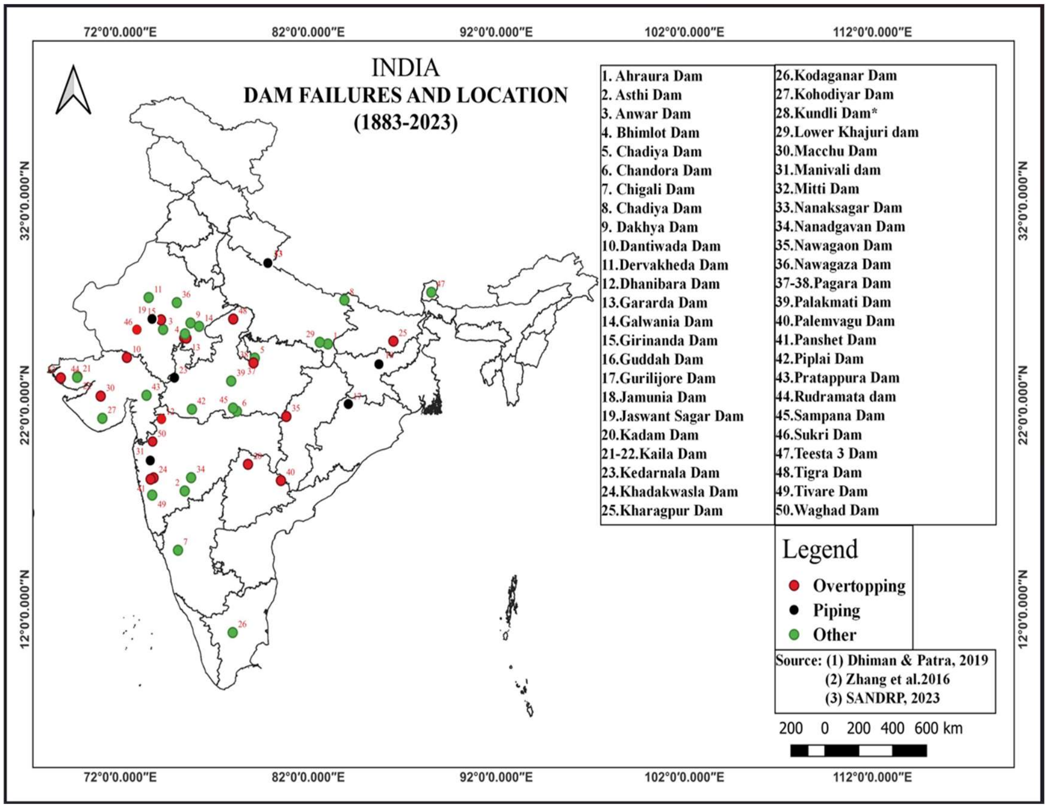
Lower Khajuri	Earth	Concrete Faced	16	1949	1949	Quality problem	-	43
Machchu	Earth & concrete	Composite	22.56	1972	1979	Overtopping	Inadequate spillway capacity	100.55
Manivali	Earth	-	18.4	1975	1976	Quality Problem	Seepage/ Piping	4.8
Mitti	Earth	Corewall	17.0	1982	1988	Overtopping /Breaching	Insufficient capacity of spillway	17.40
Nanaksagar	Earth	Homogeneous	16.5	1962	1967	Breached	Piping in foundation	209.80
Nandgavan	Earth	Composite	22.51	1968	2005	Overtopping	Wall collapse	2.06
Nawagaon	Earth	-	16	1958	1959	Overtopping	-	-
Nawagaza	Earth	-	-	1955	1961	Breaching	-	-
Pagara 1	Masonry	Gravity	30.5	-	1923	Overtopping	Insufficient spillway capacity	166
Pagara 2	Concrete	Gravity	27.3	1927	1943	Overtopping	Insufficient spillway	100
Palakmati	Earth	-	14.60	1942	1953	Sliding Failure	-	-

Palemvagu	Earth	Homogeneous	13	U/C	2008	Overtopping	-	35
Panshet	Earth	Core wall	63.56	1961	1961	Overtopping	-	310.61
Piplai	Earth	-	16.73	1998	2005	Breaching	-	-
Pratappur	Earth	Homogeneous	10.67	1891	2001	Breaching		4.12
Rudramata	Earth	Corewall	27.58	1959	2001	Base Type Failure due to earthquake	Liquefiable layer beneath foundation	61.53
Sampna	Earth	-	21.03	1956	1964	Slope Failure	Inappropriate Material	-
Sukri	Earth	-	-	-	1955	Breaching	Seepage through Foundation	-
Teesta 3	Rockfill	Concrete Faced	60	-	2023	Breaching	Inundation due to GLOF*	5.08
Tigra	Masonry		24.03	1914-17	1917	Overtopping	Sliding	-
Tivare Dam	Earth	-	-	2004	2019	Breaching	Weakening of structure	2.451
Waghad	Earth	Homogeneous	32	1883	1883	Overtopping	-	17

Sources: (1) Dhiman & Patra, 2019; (2) Zhang et al.2016; (3) SANDRP, 2023. *(GLOF) Glacial Lake Outburst Flood

Map 6.1

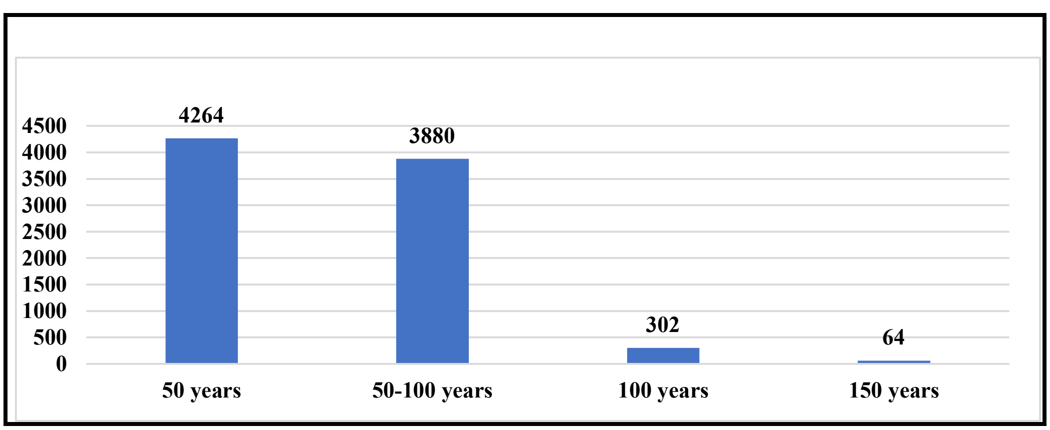
Dam Failures in India: Location of Failed Dams



*Data of dam location is not available

Figure 6.1

Dams in India: Constructed Dams in different Age Groups



Source: Harsha, 2019

Figure 6.2

Dam Failures in India: Statistics for Number of Failures as per Dam Type

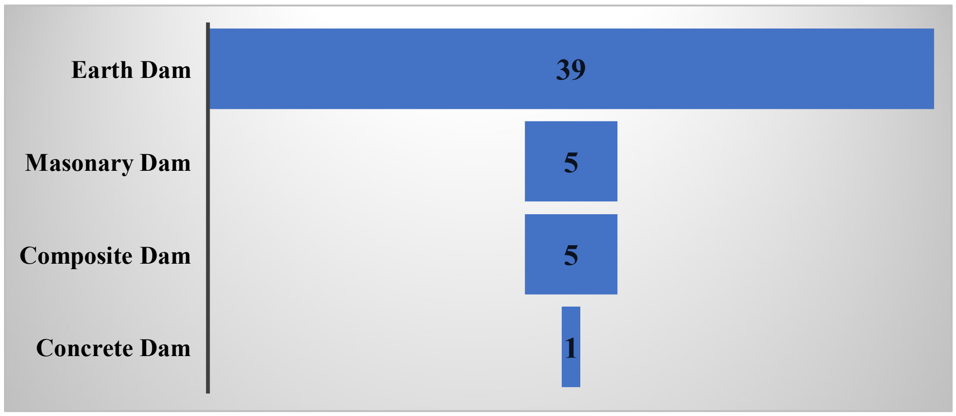


Table 6.3

Dam Failures in India: State wise List of Piping and Overtopping

Piping and Overtopping Cases in Madhya Pradesh

Name of the Dam	**Year of Failure**	**Height (m)**	**Type**	**Piping**	**Overtopping**
Palakmati Dam	1953	14.6	Earth	No	Overtopping followed by sliding
Nawagaon Dam	1959	16	Earth	No	Overtopping led to breach
Kedarnala Dam	1964	20	Earth	No	Breaching
Chandora Dam	1991	27.3	Earth	No	Breaching
Jamuniya Dam	2001	15.4	Earth	Piping	No
Chandiya Dam	2008	22.5	Earth	No	Breaching

Piping and Overtopping Cases in Rajasthan

Name of the Dam	Year of Failure	Height (m)	Type	Piping	Overtopping
Girinanada Dam	1954	12.2	Earth	No	Overtopping followed by Breaching
Anwar Dam	1957	12.5	Earth	No	Breaching
Gudah Dam	1957	28.3	Earth	No	Breaching
Jaswant Sagar	2007	43.38	Earth	Piping	Breaching
Garada Dam	2010	31.7	Earth	Piping	Breaching

Piping and Overtopping Cases in Gujarat

Name of the Dam	Year of Failure	Height (m)	Type	Piping	Overtopping
Dantiwada Dam	1973	60.96	Earth	No	Overtopping due to floods
Machchu Dam	1979	22.56	Composite Dam	Piping and Breaching	No
Mitti Dam	1988	16.2	Earth	No	Overtopping led to Breaching
Pratappura Dam	2001	10.67	Earth	No	Breached due to floods

Piping and Overtopping Cases in Maharashtra

Name of the Dam	Year of Failure	Height (m)	Type	Piping	Overtopping
Panshet Dam	1961	53.8	Earth	Piping	No

Khadakwasla Dam	1961	60	Composite	No	Overtopping
Nandgavan Dam	2005	22.51	Earth	No	Overtopping due to heavy rain

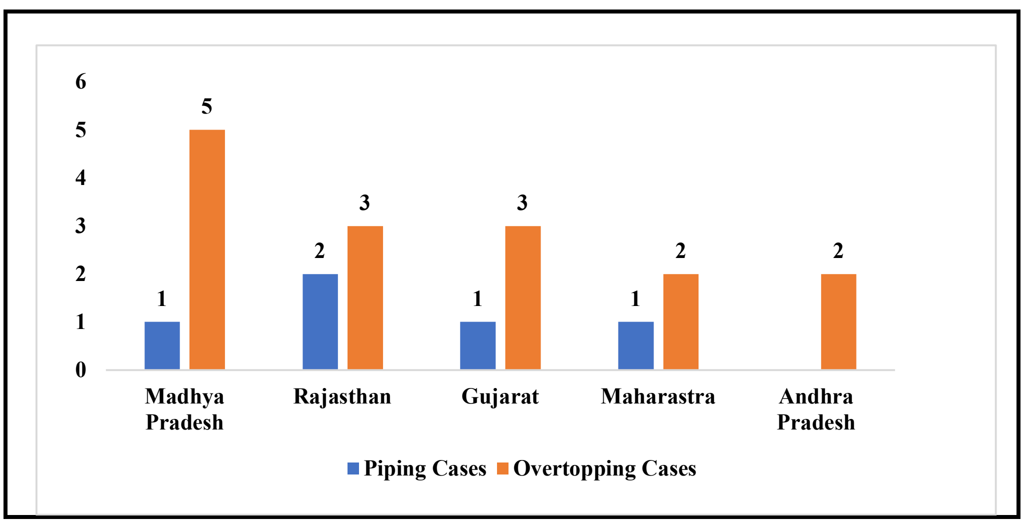
Piping and Overtopping Cases in Andhra Pradesh

Name of the Dam	Year of Failure	Height (m)	Type	Piping	Overtopping
Kaddam Dam	1995	22.5	Earth	No	Overtopping led to Breaching
Palem Vagu Dam	2008	13	Earth	No	Overtopping due to floods

Source: Talukdar & Dey, 2019

Figure 6.3

Dam Failures in India: Geographical Distribution



6.1.2 Dam Failures in India and Statistics

We have collected data regarding 50 cases of dam failures occurred in India. Table 6.4 shows the reservoir capacities of 50 failed dams in India. Most reservoirs have capacities less than 10 million cubic metre among the cases with known capacities. Table 6.3 & Figure 6.3 shows the height wise number of failed dams. Predominantly, of the dams (about 36%) that have failed were dams having height between 20-30 m and 32% failed dams have height below 20m.Table 6.5 shows the construction times of the failed dams. The dams which suffered the highest rate of failure are mainly constructed during two periods, 1950–1960 and 1960–1970.Table 6.6 shows the age of the dams at the time of failure. The data indicates that all types of dams especially earth dams are most likely to fail within its first year of service, during the initial impounding during the first year after construction. Ageing is also a critical factor in dam failures as 6% dam were having 60-100 years age at the time of failure.

Table 6.4

Dam Failures in India: Categorization of Failed Dams as per Height

Height of Dam (m)	**No. of Cases**
<15m	6
15-20 m	10
20-30m	18
30-40m	3
40-50m	2
>50m	4
Unknown	7
Sum	50

Source: Compiled by Author

Figure 6.4

Dam failures in India: Percentage of Dam Failures as per Height

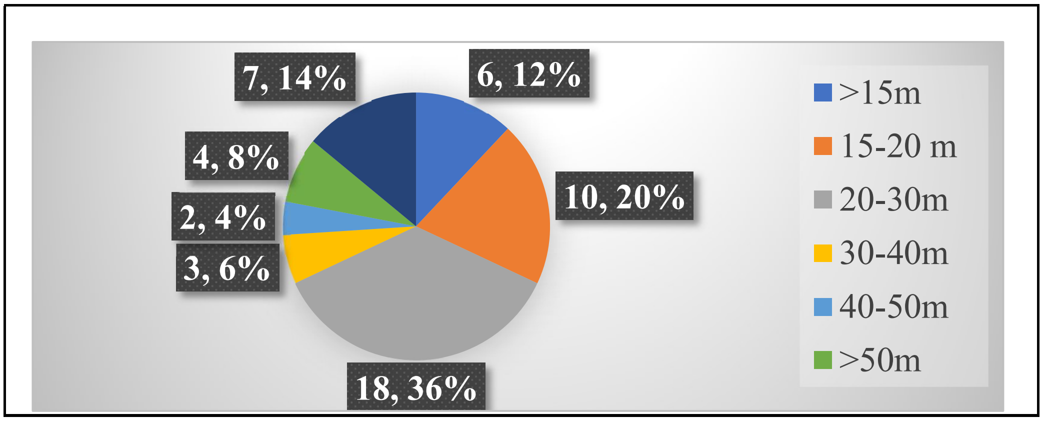


Table 6.5

Dam Failures in India: Failed Dams Categorized on the basis of Storage Capacity

Storage Capacity (MCM)	No. of Dam Failures	Percentage (%)
<10	8	16
10-20	5	10
20-50	5	10
50-100	5	10
100-150	3	6
150-200	1	2
200-250	2	4
>250	2	4
Unknown	19	38
Sum	50	100

Table 6.6

Dam Failures in India: Failed Dams Categorized on the Basis of Construction Year

Year of Construction	Number of Cases	Percentage (%)
Before 1900	5	10
1901-1910	0	0
1911-1920	1	2
1921-1930	4	8
1931-1940	0	0
1941-1950	2	4
1951-1960	14	28
1961-1970	7	14
1971-1980	5	10
1981-1990	2	4
1991-2000	1	2
After 2000	2	4
Unknown	7	14
Sum	50	100

6.1.3 Dam Failures and Characteristics

Fig.6.5 depicts the percentage wise data regarding causes for all dam failures in India. As per data, the most common cause of dam failures is Overtopping and Quality problem. Nearly 70% of all failures occurred due to these two causes. Fig.6.6 portrays the percentage wise data for sub-causes of quality problems in earth dam failures. It is evident that Insufficient spillway capacity is the principal influence factor on overtopping and 14% of quality problems are associated with piping in the dam body or foundation.

Table 6.7

Dam failures in India: Age wise Categorization of Dams

Age of Dam	**Number of Dam Failures**	**Percentage (%)**
Under construction	1	2
0-1	17	34
1-5	3	6
5-10	6	12
10-15	2	4
15-20	2	4
20-30	3	6
30-40	2	4
40-60	2	4
60-100	3	6
100-150	2	4
>150	0	0
Unknown	7	14
Sum	**50**	**100**

6.1.3.1 Overtopping

Overtopping occurs when the water surface in reservoir heightens more than the dam elevation. It is the process which takes place when the height of water surface in reservoir exceeds the dam elevation. Overtopping mainly occurs in the event of Flooding which is the most common cause of dam failure in earthen dam. Moreover, Inadequate spillway/ reservoir capacity/ wrong flood design/ failure of water outlet system also results in overtopping. For earthen dams, failure due to overtopping starts at downstream and progresses towards the top. This is followed by the creation of an opening at crest and its gradual expansion in the shape of a trapezoid (Fig.6.7) (Central water commission, 2018b).

Figure 6.5

Dam Failures in India: Causes and Percentage of Failed Dams

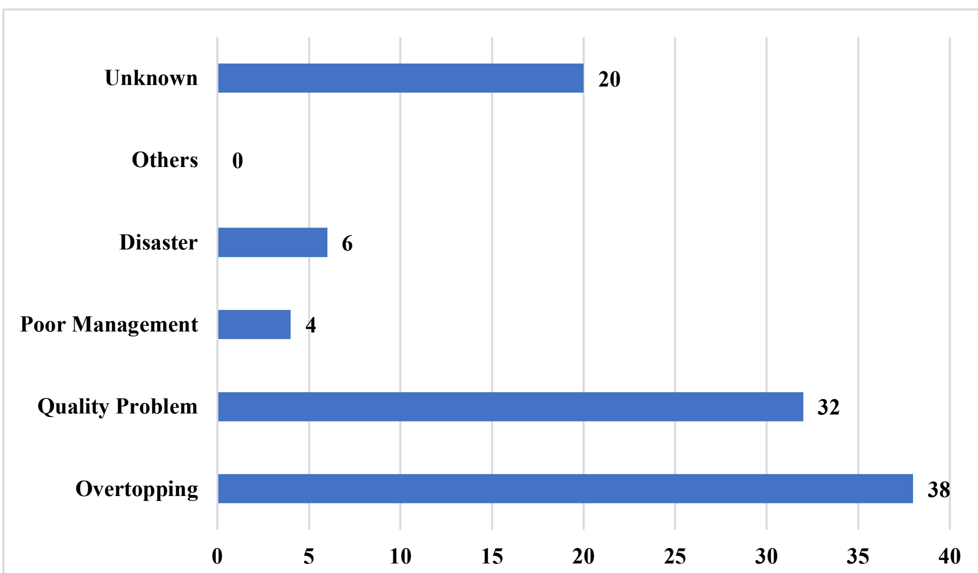
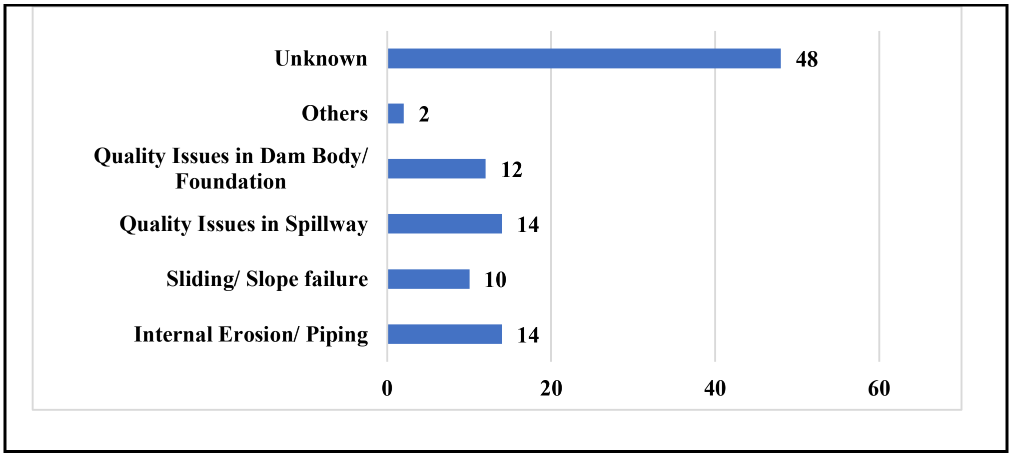


Figure 6.6

Dam Failures in India: Sub-causes of quality problems and Percentage of Failed Dams



6.1.3.2 Piping/ Internal erosion

Seepage in dam core and erosion of fine sediments results in creating a circular opening and a pipe connecting the reservoir water to the downstream. This process is called Piping. As the erosion continues, the circular opening reaches the top of dam and gradually expands in trapezoidal shape (Fig.6.8). As per Central water commission, 2018b, Piping and Internal erosion has four stages namely Initiation of erosion begins, followed by continuation of erosion and formation of pipe consequently resulting in breach formation.

6.1.4 Analysis of Subdivided Earth Dams

According to Zhang et al. 2016b, Earth dams are subdivided in these four types:

- Homogeneous earth fills dams
- Zoned earth fills dams
- Earth fill dam with core walls
- Concrete faced earth fill dams

Out of these four types, Homogeneous dams account for 22.7% failures and 11.36% failures occurred in composite dams (Table 6.7). From Table 6.8. it is clear that Piping/quality problem is the dominant cause of failure only in Homogeneous dams whereas overtopping is the most common cause of failure in all four types of earth dams.

Figure 6.7

Dam Failure: Overtopping and Breach Progression

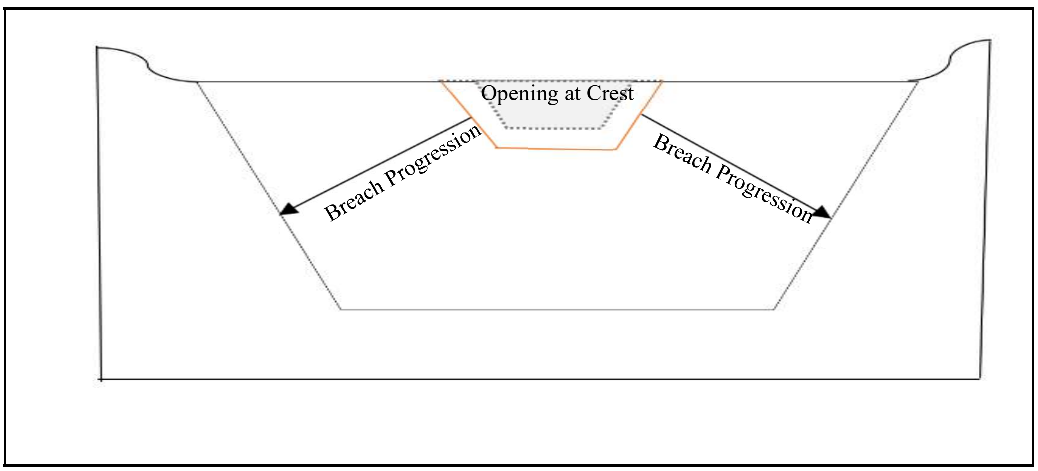


Figure 6.8

Dam Failure: Piping and Breach Progression

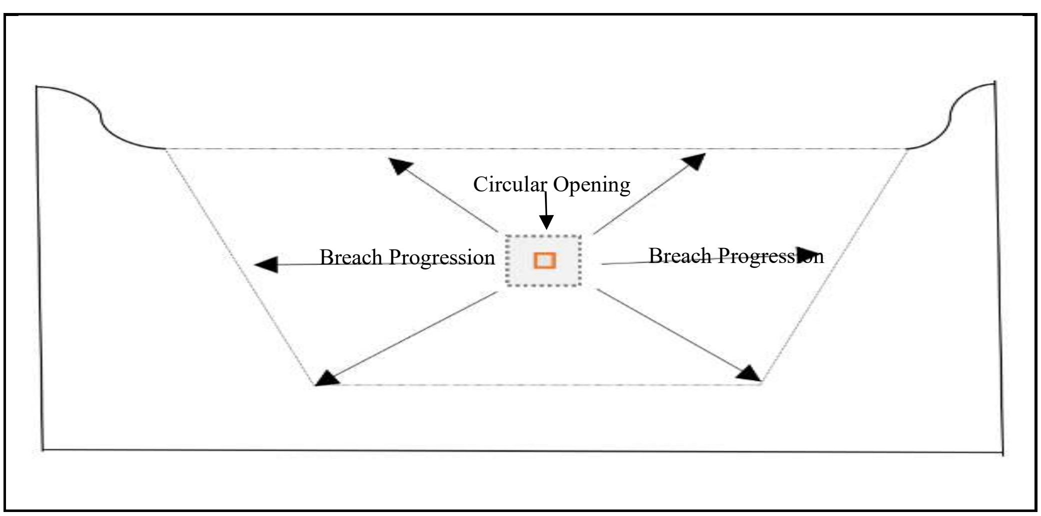


Table 6.8

Dam Failures in India: Percentage Wise Number of Failure cases for Different Type of Embankment Dams

Types of Dams	**Number of Cases**	**Percentage (%)**
Homogeneous Earth fill	10	22.7
Composite Earth Fill	5	11.36
Earth fill with Core wall	3	6.8
Concrete- Faced Earth fill	3	6.8
Unknown	23	52.2
Sum	**44**	**100**

Table 6.9

Dam failures in India: Different Types of Embankment Dams and Summary of Failure Causes

Type of Dam	**Overtopping**	**Piping**	**Quality Problem**	**Poor Management**	**Disaster**	**Sum**
Homogeneous Earth fill	5	3	2	-	-	10
Composite Earth Fill	4	-	-	-	-	4
Earth fill with Core wall	2	-	-	-	1	3
Concrete- Faced Earth fill	-	-	2	-	1	3

Table 6.10

Dam Failures in India: Potential Locations at Risk

Dam Type	Foundation/ Structural Failure	Insufficient Spillway	Dam Body
Earthen Dams	Low Risk	Medium Risk	High Risk
Masonry/Concrete Dams	Low Risk	High Risk	Low Risk

6.1.5 Main Findings

Based on the statistical analysis of 50 previous Dam failures in India, key findings are as follows:

- 39 out of 50 occurrences included earthen dam failures, indicating that these dams are more likely to fail.
- The primary reasons for Indian dam collapses are quality issues and breaching brought on by overtopping.
- Among 39 dam failures of Earthen dams, 22% occurred only in homogeneous dams, caused mainly due to overtopping and piping is also identified as an important cause of failure. But piping seems less likely to occur in core wall earth dams.
- For earthen dams in India, dam body is identified as the high-risk potential location followed by insufficient spillway which is another potential risk location.

6.2 Potential Failure Risks to Ranjit Sagar Dam

In this section, Potential failure Risks to Ranjit Sagar Dam and its Safety are evaluated. The study is based on :

1. Lessons learnt from analysis of previous Dam failure cases in India

2. Hydrological and Geo-tectonic Risks as reviewed from various reports and research articles.

6.2.1 Lessons Learnt from Previous Dam Failure Cases in India

Examining past dam failures and incidents offers valuable insights into how a similar event could occur at a specific dam[9]. According to Jain et al. 2023, studying past dam failures offers important understanding that help shape engineering practices, risk evaluations, and regulations to prevent future incidents. Gaining knowledge from past dam failures and incidents is essential to preventing issues caused by these hazards (Adamo et al.2020).This section provides insights into potential dam failure risks to Ranjit Sagar Dam as summarised under section 6.1.5 above. Following inferences can be drawn:

- First, earthen dams in India are more prone to failure, so this can be an important factor regarding Ranjit Sagar dam safety.
- Secondly, as Ranjit Sagar Dam is an Earthen cum Rockfill Dam (Table 6.11) with impervious core, based on the findings of previous history of Indian Dam Failures, there may be potential risk of overtopping due to flooding as piping seems less likely to occur in Earth Core wall dams in previous earthen dam failures in India.
- Next, in case of failure, body of Ranjit Sagar Dam may be a high-risk potential location where breach may initiate.
- Lastly, quality issue in Ranjit Sagar Dam's structure/components may be a potential cause of failure as found in analysis of previous dam failures in India.

Moreover, seepage may also be a potential cause of failure as final plugging of Tunnel T-1 and curtain grouting of Ranjit Sagar Dam are yet to be completed (Department of Water Resources, Punjab, 2021) which are essential to reduce the seepage through dam foundation (Zhang et al.2022).

All the above-mentioned findings underscore the need for proper maintenance and regular inspection of dam's structure/components by dam engineers and dam

[9] https://damfailures.org/lessons-learned/the-study-of-past-incidents-and-failures-aids-in-the-assessment-of-existing-dams/

authorities. Routine assessments conducted by dam engineers and authorities help identify potential weaknesses, structural wear, or operational inefficiencies before they escalate into serious issues. By implementing thorough inspection protocols and maintenance strategies, authorities can enhance the dam's longevity, ensure public safety, and prevent catastrophic failures. Additionally, regular monitoring allows for timely repairs and upgrades, ensuring that the dam continues to function efficiently under varying environmental and operational conditions.

Table 6.11

Ranjit Sagar Dam : Features

Features of Ranjit Sagar Dam	Facts/ Numbers
Dam Type	Earth and Rockfill with Impervious Core
Materials used to Construct its Body	Core, Filter, Sand, Gravel and Boulder Fill, Rip Rap
Gross Storage Capacity	3280 million cubic meters
Probable Maximum Flood	535.6 m
Spillway Design Flood	533.73m
Age of Dam	24 Years
Silting of Reservoir	212 years

Source: Documents from Office of Executive engineer, Ranjit Sagar Dam, Jugial (Punjab)

6.2.2 Hydrological and Geo-Tectonic Factors

The safety of water reservoirs is influenced by geological, hydrological, and geotechnical factors (Ukpai, 2020). Floods contribute to the hydrological stress on dams. As a result, shifts in climatic conditions are expected to impact the hydrological safety of dams (Lompi et al.2023). Geological hazards (which may include presence of karsts, soluble rocks, hidden faults or hazardous material) affecting dams, play a crucial role in determining their safety and long-term performance (Adamo et al.2020). This section put forth numerous hydrological and geo-tectonic factors which may pose potential failure risks for Ranjit Sagar dam. First sub-section deals with Hydrological factors followed by next sub-section which encompasses the geo-tectonic factors.

6.2.2.1 Detail about Inflow in the Reservoir/Hydrological Details

As presented in Table 6.12, the total catchment (Map 6.3) of the Ranjit Sagar reservoir is about 6086 km sq. Its catchment receives 1388mm of mean annual rainfall, majority of it occurs during Monsoon season. Major source of water inflow into the reservoir is Chamera Dam 1 (Map 6.2). It takes 3 to 4 hours (approximately), for flood water of Chamera Dam 1 to reach Ranjit Sagar dam reservoir. Some local streams are also the minor sources of inflow into reservoir with five Khads namely Karnal Khad (Punjab), Nani Khad (H.P), Garnal Khad(J&K), Biani Khad(J&K), and Chirl Khad (J&K) which contribute 15 to 20% inflow during monsoon. These details imply that Ranjit Sagar Dam is likely to be at high risk of failure due to flooding/overtopping during monsoon season when inflow into the reservoir increases manifold and in the absence of an Advance Inflow Forecasting System (Jain et al.2018), the dam may become more vulnerable to hydrological failure in case there is excessive rainfall in the catchment of Ranjit Sagar Dam reservoir as the Ravi River Basin/ Ranjit Sagar Reservoir Catchment (Map 6.3) is already experiencing the effects of climate change, including glacier melting and a growing risk of Glacial Lake Outburst Floods (GLOFs)[10]. Thus, dam authorities and decision-makers must adapt to the evolving challenges posed by climate change in the Ranjit Sagar Dam catchment, ensuring they are equipped to address its impacts on dams effectively. Additionally, Issac et al.2024 emphasizes the crucial need to consider Glacial Lake Outburst Floods (GLOFs) in spillway capacity evaluations, alongside the inflow design flood. Incorporating these factors is essential for strengthening the hydrological security of these vital energy infrastructures in the Ravi River Basin.

6.2.2.2 Geological and Tectonic Details of Ranjit Sagar Dam

The area is occupied by rocks of Shivalik Hills and recent alluvium (Map 6.4). The rocks are of sedimentary origin and consist of detrital material from various rocks types which are weak and exposed to denudational process (Plate 6.2). In general, rocks are consisting of mature grains and sediments of quartz, clays, micas and heavy minerals. The strength of materials decreases as the particle breakage increases. (Gupta, 2009).

[10] https://www.jkforest.gov.in/assets/pdf/publications/DPR_Ravi_overview.pdf

The rocks of upper Shivalik have been assigned a Quaternary i.e. Pleistocene age (Table 2.1).

Table no. 6.12

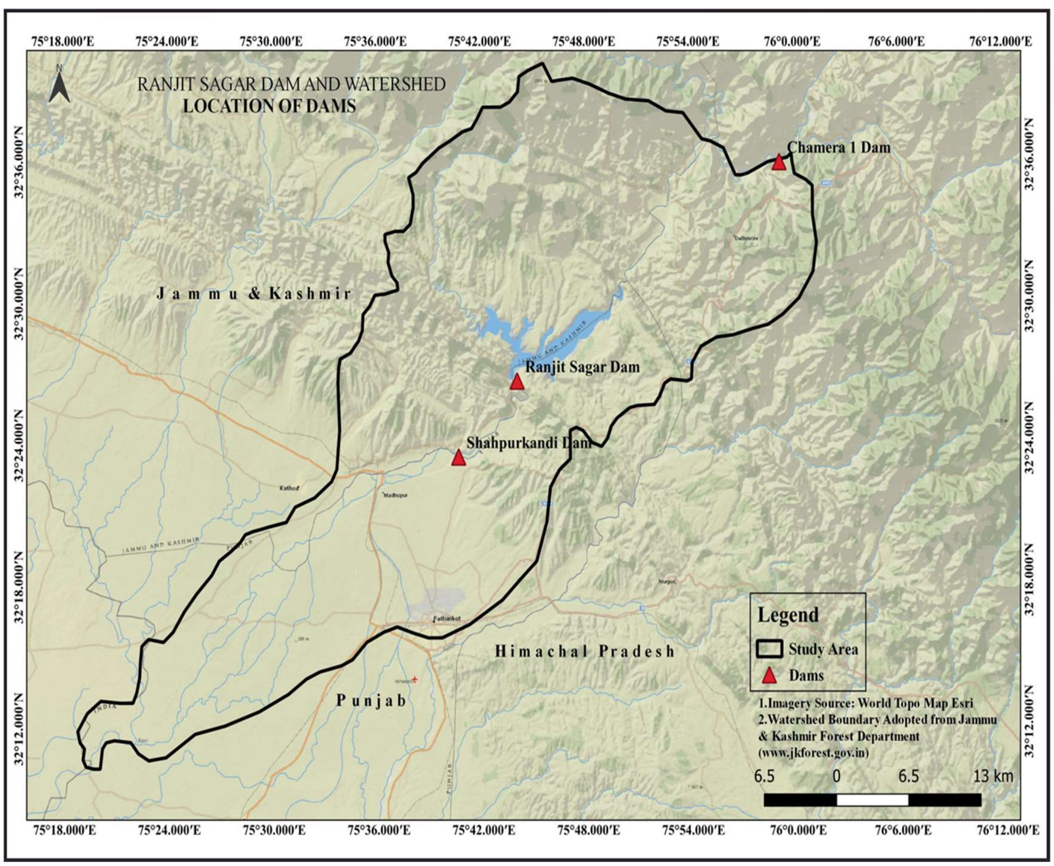
Ranjit Sagar Dam: Hydrological Details

Inflow Detail	Fact/Number
Total Catchment of the Reservoir	6086 km sq
Mean Annual Rainfall in Reservoir's Catchment	1388mm
Main Source of Inflow	Chamera1 Dam
Other Sources of Inflow	15-20% from Local Khads

Source: Official Report, Office of Chief Engineer Ranjit Sagar Dam, Jugiyal, Punjab

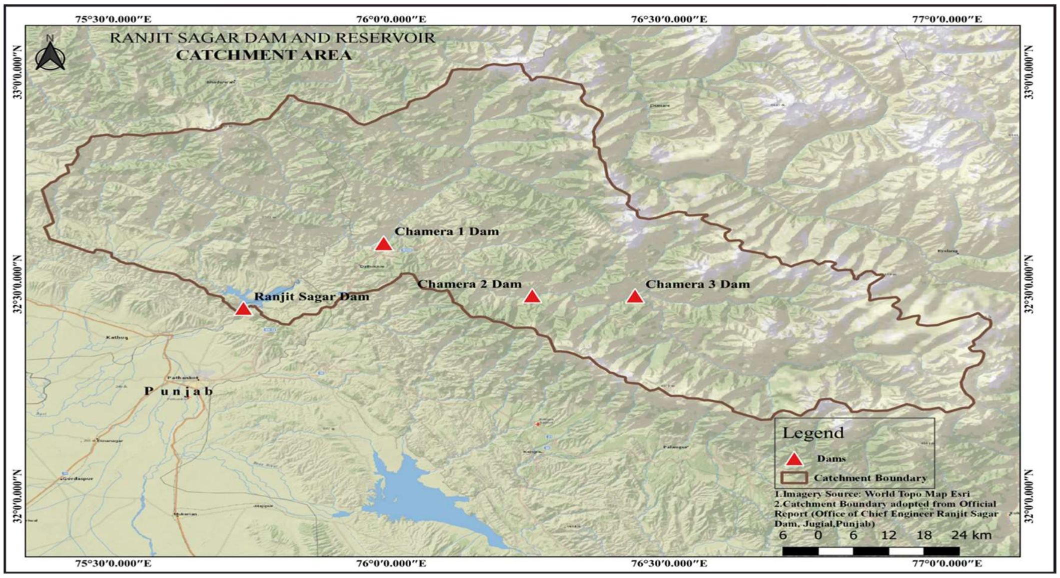
Map 6.2

Ranjit Sagar Dam Watershed: Dam Projects



Map 6.3

Ranjit Sagar Dam : Catchment Area of Reservoir



Map 6.4

Ranjit Sagar Dam Watershed: Location of Folds and Faults

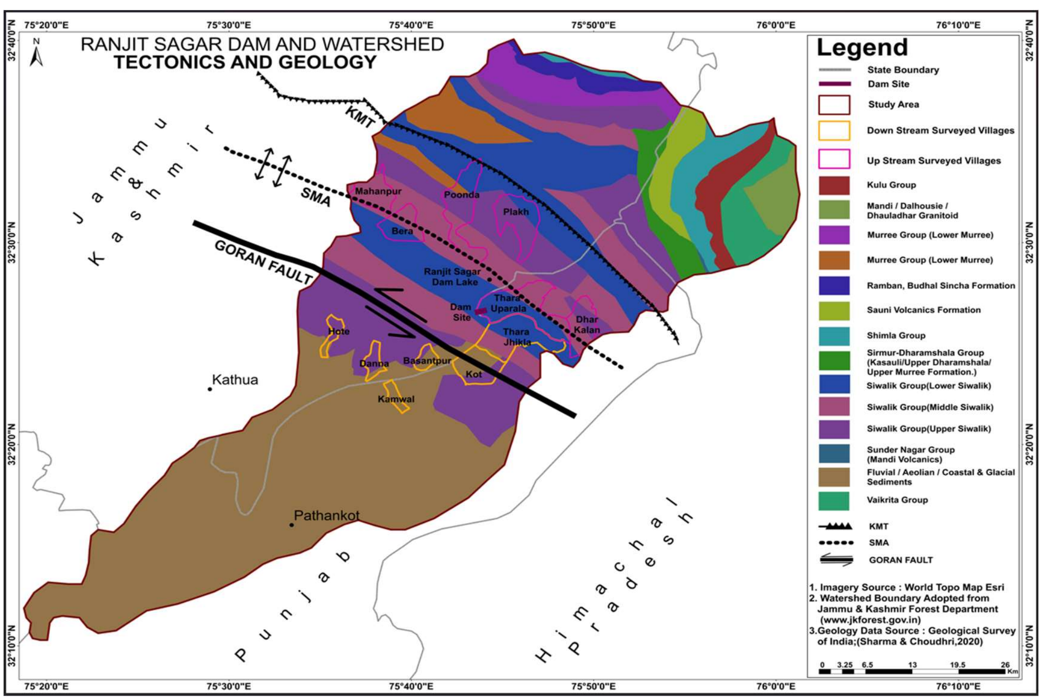


Table 6.13

Ranjit Sagar Dam and Watershed: Features of Local Folds/Faults

Local Folds/Faults	Features
Kishanpur-Mandli Thrust (KMT)	Extension of Jawalamukhi Thrust in the east and Riasi Thrust in the west (Taloor et al. 2023)
Surin-Mastgarh Anticline(SMA)	Characterized by a broad fold extending between Ravi River and Chenab River for 250 km (Biswas & Sain, 2023)
Goran Fault	Extends between Basantar river (J&K) and Beas River (Punjab) for 100km (Sharma& Choudhri, 2020)

This sub-Himalayan region has numerous local folds and faults (Taloor et al.2023). Ranjit Sagar Dam watershed includes Goran fault in the downstream region, Surin-Mastgarh Anticline and Kishanpur-Mandli Thrust in the upstream region of the Dam (Map 6.4). Table 6.13 illustrates a detail about local folds and faults present in the region. The next sub-sections elaborate the potential Geo-tectonic and seismic risks to the safety of Ranjit Sagar Dam as follows:

Potential Geo-Tectonic Risks to Ranjit Sagar Dam

Sharma & Choudhri, 2020 studied the tectonic set up based on tectonic morphometric indices of various rivers and Ravi River in Kathua District. It was revealed that there is presence of active strike slip fault known as Goran Fault (Map 6.4) in proximity of Ranjit Sagar Dam. The fault line passes through the surveyed village Kot (Punjab) and Basantpur (J&K) lying in downstream region of the dam. The presence of Goran Fault indicates an active tectonic terrain in the vicinity of Ranjit Sagar Dam which may be a threat to the dam safety and vulnerable downstream communities. Keeping in view the tectonic setup of the region, the Construction of Shahpur Kandi Barrage downstream of Ranjit Sagar Dam is also not safe. These findings underscore the need for further geo-technical investigations of the Ranjit Sagar dam watershed and adopting requisite measures ensuring safety of dams and vulnerable population in Ranjit Sagar Dam Watershed.

- *Seismic/Liquefaction Risk*

As Ranjit Sagar Dam lies in Seismic zone IV (Map 6.5) due to which the region is highly prone to seismicity which seems another critical factor posing potential risk of failure to the Ranjit Sagar dam. The high seismicity in the region has number of interrelated aspects such as landsliding/rock sliding (Plates 6.1, 6.3, 6.4) and liquefaction in the region which may act as catalytic factor considering active tectonic setup of the region. Further as stated by Kalateh et al.2025 that in case of an earthquake, liquefaction of saturated sands in a dam foundation can occur when pore water pressure increases due to the compaction of the soil structure. This pressure buildup causes a reduction in soil strength, which ultimately lead to failure. Additionally, Ansari et al.2022 in a study about Liquefaction Hazard Assessment in Jammu region found that areas along the Ravi River bank in Kathua District have young alluvium and thus are highly prone to Liquefaction. Thus, liquefaction vulnerability around the Ranjit Sagar Dam region may be a potential dam failure risk. So, considering liquefaction mitigation measures is essential for safety of Ranjit Sagar Dam.

Map 6.5

Ranjit Sagar Dam: Seismic Zone

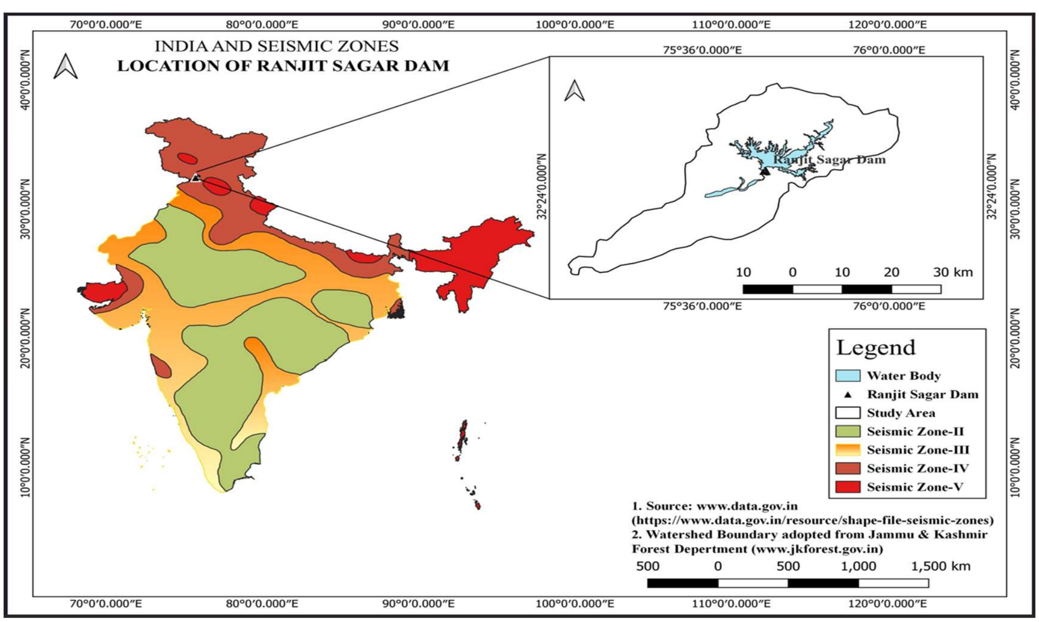


Plate 6.1

Source: Field work, 2023 A view of damaged road due to landsliding near the Ranjit Sagar Dam

Plate 6.2

Source: Field work, 2023 The picture depicts Siwalik rocks exposed to denudation in vicinity of Ranjit Sagar Dam

Plate 6.3

Source: Field work, 2023 Picture portrays the Warning Sign Board as installed in Rock Sliding area near Ranjit Sagar Dam

Plate 6.4

Source: Field Work, 2024 Rock slides near Ranjit Sagar dam site as captured during Field Visit

From the above discussion, it can be concluded that the presence of Goran fault in proximity to Ranjit Sagar Dam and Shahpur Kandi Dam, high seismicity in the region, Liquefaction vulnerability of the area around Ranjit Sagar Dam are major potential geo-tectonic failure risks to the dams in Ranjit Sagar Dam Watershed. Also, the rock structure in the region where Ranjit Sagar dam is located is weak and exposed to denudational process making the area more vulnerable to land sliding and thus pose a potential threat of dam failure due to geological/structural mode of failure as also pointed out by Gupta, 2009 that strength of material used in the construction of dam decreases as the breakage of the particles increases. All the above -mentioned potential causes highlight the need of immediate action to be taken by dam authorities and government for conducting an in-depth and integrated hydro-geo-tectonic investigations considering climatic change induced GLOF in the Ranjit Sagar Catchment and presence of Goran Fault in the Ranjit Sagar Watershed. A multi-disciplinary approach involving geo-tectonic studies, environmental studies and hydrological studies along with regular inspection, maintenance and updating the dam's structural components/infrastructure is recommended for ensuring safety of Ranjit Sagar Dam in particular and other constructed or planned dams in the Ranjit Sagar Dam watershed.

6.3 Perception of People residing Upstream and Downstream of Ranjit Sagar Dam about Flood occurrence and Dam Safety Measures

This section illustrates a survey-based analysis of people's perceptions regarding flood occurrence and Ranjit Sagar Dam safety. Respondent's views on Dam Failure/Flooding Risk and Adequacy of Dam Safety measures are assessed using Likert Scale and each impact is rated across five categories: Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree. Further, survey responses of people from Upstream and Downstream regions of Ranjit Sagar dam are represented graphically using Diverging Bar Graphs as shown in Figure 6.9 & Figure 6.10 respectively. Additionally, to check if people's perceptions of flood occurrence and dam safety are shaped by demographic factors such as Age and Occupation, hypothesis testing is done using Chi-Square analysis.

6.3.1 Graphical representation of Survey Responses

As presented in Figure 6.9 & 6.10 and Table 6.14 & 6.15, the data depicts the responses for Impacts on flood occurrence and dam safety specifically focusing on adequacy of dam safety measures. There seems a widespread disagreement for increased floods among the respondents of both upstream and downstream regions. On the other hand, regarding adequacy of dam safety measures, large number of the upstream and downstream respondents have a significantly higher level of disagreement, yet some of them also had positive responses indicating that either these respondents are directly involved in dam operations and implementation of dam safety measures or they are aware of measures taken by dam authorities to ensure dam safety.

6.3.1.1 Perceptions of People Living in Upstream Regions

From Table no. 6.16, we can analyse the relationship between different occupation and level of agreement for adequate dam safety measures. Noteworthy, association between Age, Education and Dam Failure Risk is not significant.

Table 6.14

Ranjit Sagar Dam: Survey Responses on Flood Occurrence and Dam Safety (Upstream)

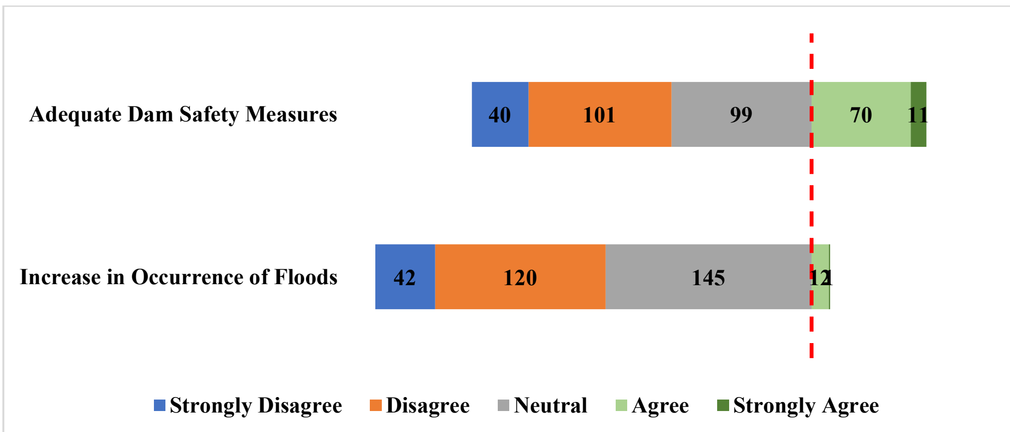
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Increase in Occurrence of Floods	42 (13.13)*	120 (37.50)	145 (45.31)	12 (3.75)	1 (0.31)	320 (100.00)
Adequate Dam Safety Measures	40 (12.46)	101 (31.46)	99 (30.84)	70 (21.81)	11 (3.43)	321** (100.00)

*Number of responses (percentage) ** Response counts vary as not all respondents answered every question.

Observation: Table 6.16 displays responses of upstream respondents categorized by occupation on the level of agreement or disagreement concerning adequacy of dam safety measures. Among all respondents who express disagreement regarding adequacy of dam safety measures, which is 31.4%, 8.4% are dam employees followed by farmers (7.8%) and Government employees (7.5)%. On the contrary, there are 21.4% people who indicate agreement on adequacy of dam safety measures, 13.4% are dam employees followed by people engaged in business sector which is 2.8%. To assess the association, we used Chi-Square Test and as the analysis shows (Table 6.16), the Chi-square value for 16 degrees of freedom and p-value (.000) is 46.874 which is significant at 1% level indicating the validation of hypothesis. Hence, it is generalized that there exists statistically significant association between occupation and level of agreement/disagreement on adequate dam safety measures. It means that people with different occupational background view adequacy of dam safety measures differently. It implies that farmers express significant concerns likely due to impact of dam safety on their livelihood and community where as some dam employees and individuals in the business sector have greater confidence in the adequacy of dam safety measures. It may suggest that these groups have better awareness, direct involvement, or vested interests in dam operations and safety protocols.

Figure 6.9

Ranjit Sagar Dam: Survey Responses on Flood Occurrence and Dam Safety (Upstream)



Source: Field work, 2022-2024

Table 6.15

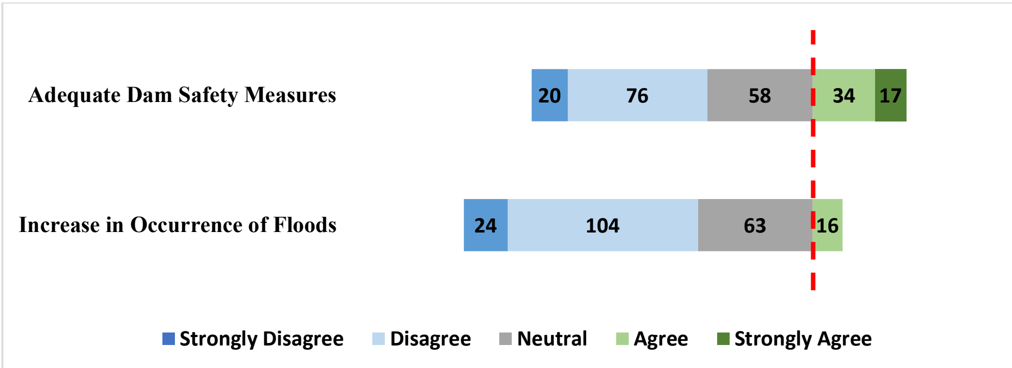
Ranjit Sagar Dam: Survey Responses on Flood Occurrence and Dam Safety (Downstream)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Increase in Occurrence of Floods	24 (11.59)*	104 (50.24)	63 (30.43)	16 (7.73)	0 (0.00)	207 (100.00)
Adequate Dam Safety Measures	20 (9.76)	76 (37.07)	58 (28.29)	34 (16.59)	17 (8.29)	205** (100.00)

*Number of responses (percentage); **Number of respondents vary as some respondents didn't answer these questions during the survey

Figure 6.10

Ranjit Sagar Dam: Survey Responses on Flood Occurrence and Dam Safety (Downstream)



Source: Field work, 2022-2024

Table 6.16

Ranjit Sagar Dam and Upstream region: Association between Occupation and Dam Failure Risk/Flooding (Adequate Dam Safety) during Operational Phase

	Occupation	Adequate Dam Safety Measures: Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	12(3.7)	27(8.4)	33(10.3)	43 (13.4)	10 (3.1)	125 (38.4)	46.874 ***
	Farmer	12(3.7)	25(7.8)	29(9.0)	7(2.2)	1(0.3)	74 (23.1)	
	Business	4(1.2)	9(2.8)	13(4.0)	9(2.8)	0	35 (10.9)	
	Government Job	9(2.8)	24(7.5)	15(4.6)	7(2.2)	0	55 (17.1)	
	Others	3(0.9)	16(5)	9(2.8)	4(1.2)	0	32 (9.9)	
	Total	40 (12.4)	101 (31.4)	99 (30.8)	70 (21.8)	11 (3.4)	321 (100)	

() represents percentage and *** represents significance level at 1%

6.3.2.2 Perceptions of People Living in Downstream Region

From Table no. 6.17 & 6.18, we can analyse the relationship between different occupation, Age Group and level of agreement for adequate dam safety measures.

Observation: Table 6.17 portrays the occupation wise responses on level of agreement/disagreement on adequate dam safety measures for Ranjit Sagar dam. About 37.1 % downstream respondents (majority of them are farmers) have disagreement about adequacy of dam safety measures. On the other hand, 16.6 % (majority of them are dam employees) agree for the adequacy of dam safety measures. To assess the association, we used Chi-Square Test and as the analysis shows (Table 6.17), the Chi-square value for 16 degrees of freedom and p-value (.000) is 105.20 which is significant at 1% level indicating the validation of hypothesis. Hence, it is generalized that there exists statistically significant association between occupation and level of disagreement on adequate dam safety measures. It means that occupation shapes the people's views on adequacy of dam safety measures. Farmers express negative views regarding dam safety measures likely due to impact of dam safety on their livelihood and community where as dam employees have a positive outlook regarding dam safety measures as they are directly involved in the dam operations and have more awareness and trust on dam safety measures taken by dam authorities.

Observation: Table 6.18 summarizes the responses of various Age groups regarding level of agreement/disagreement on adequate dam safety measures for Ranjit Sagar dam. About 37.1 % downstream respondents (majority of them having age >36 years) express strong disagreement regarding adequate dam safety measures and about 9.8% respondents strongly disagreed for the same. To assess the association, we used Chi-Square Test and as the analysis shows (Table 6.18), the Chi-square value for 8 degrees of freedom and p-value (.001) is 25.100 which is significant at 1% level indicating the validation of hypothesis. Hence, it is generalized that there exists statistically significant association between Age group and level of disagreement on adequate dam safety measures. Thus, how people perceive adequacy of dam safety measures is influenced by age group. Individual having age> 36 years have strong disapproval for dam safety measures may be due to the fact that they have direct and previous experiences regarding dam failure or flash flood incidents compared to the younger individuals having age 25-36 years who seems to have less direct experience.

Table 6.17

Ranjit Sagar Dam and Downstream region: Association between Occupation and Dam Failure Risk/Flooding (Adequate Dam Safety) during Operational Phase

		Adequate dam Safety Measures						
Occupation		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Occupation	Dam Employee	2(1.0)	7(3.4)	15(7.3)	28(13.7)	17(8.3)	69 (33.7)	105.201***
	Farmer	7(3.4)	38(18.5)	20(9.8)	3(1.5)	0(0)	68 (33.2)	
	Business	5(2.4)	14(6.8)	6(2.9)	1(0.5)	0(0)	26 (12.7)	
	Govt. Job	2(1.0)	11(5.4)	7(3.4)	1(0.5)	0(0)	21 (10.2)	
	Others	4(2.0)	6(2.9)	10(4.9)	1(0.5)	0(0)	21 (10.2)	
	Total	20(9.8)	76(37.1)	58(28.3)	34 (16.6)	17(8.3)	205 (100)	

() represents percentage and *** represents significance level at 1%

Table 6.18

Ranjit Sagar Dam and Downstream region: Association between Age and Dam Failure Risk/Flooding (Adequate Dam Safety) during Operational Phase

Age		Adequate Dam Safety Measures						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Chi-Square
Age Group	>50	4(2.0)	29(14.1)	31(15.1)	22(10.7)	10(4.9)	96(46.8)	25.100***
	36-50	9(4.4)	40(19.5)	22(10.7)	11(5.4)	6(2.9)	88(42.9)	
	25-35	7(3.4)	7(3.4)	5(2.4)	1(0.5)	1(0.5)	21(10.2)	
	Total	20(9.8)	76(37.1)	58(28.3)	34(16.6)	17(8.3)	205(100)	

() represents percentage and *** represents significance level at 1%

"During construction work of Ranjit Sagar Dam, the temporary embankment got damaged and washed away two times causing flash floods downstream. So, dam failure may occur at any stage". -------------Recollected by an Upstream Respondent (Village: Thara Uparla).

"The reservoir gets filled to the highest level mostly during monsoon season. Then flood gates are opened to release excess water downstream and sometimes it is done without prior warnings" -----------Downstream Respondent

Summary: Following are the key insights derived from above study on dam failure risks and dam safety measures for Ranjit Sagar Dam:

This study identified following Potential Dam Failure Risks to Ranjit Sagar Dam

- As per analysis of data regarding previous 50 dam failures in India, earthen dams are more prone to failures due to overtopping, thus Ranjit Sagar Dam being an earthen cum core dam may has the potential failure risk due to overtopping mainly during monsoon season in absence of advanced weather and inflow forecasting system. Moreover, body of Ranjit Sagar Dam may be a high-risk location if failure occurs.

- Another potential failure risks include weak rock structure and high seismicity of the region, soil liquefaction vulnerability in case of an earthquake, presence of Goran fault, uncompleted curtain grouting in rock foundation of dam and increased Glacial Lake Outburst Floods in Ravi basin.

Considering above points, emergency action plans, including evacuation procedures and early warning systems are urgently required. To predict extreme weather effects on hydrological patterns and risks to ecosystems and water cycles, policies regarding existing and new dams in Ranjit Sagar Dam Watershed must integrate climate models. Moreover, mandatory frequent inspections must be done to monitor cracks, leaks and seismic responses to minimize the geo-tectonic risks to the safety of Ranjit Sagar Dam and other dams in its watershed. Furthermore, to evaluate risks to ecosystems and water cycles stricter EIAs must be carried out for future dams to be constructed in the Ravi River Basin. Before constructing more new dams in the region, economic policies should focus feasibility studies considering maintenance and disaster recovery costs.

Overall, dams in Ranjit Sagar Dam Watershed region, which is geotectonically and hydrologically risky, require tighter regulations, proactive disaster management, and sustainable water governance. Governments must balance economic benefits with long-term safety and environmental protection to prevent catastrophic failures.

Following inferences are drawn regarding people's perceptions on Dam Safety Measures:

- According to dam officials, dam authorities take numerous measures to ensure safety of communities residing downstream yet the people have diverse opinions regarding adequacy of dam safety measures. These perceptions are significantly influenced by occupation and age group of people as described below:
- In downstream region, dam employees perceive that there are adequate dam safety measures in place where as farmers and other occupational groups have negative outlook regarding adequacy of dam safety measures. This may be

because farmers are not directly involved in dam operations and may have experienced impact of dam safety on their livelihood and community in the past.

- Age is another factor influencing people's views on adequacy of dam safety measures. Generally, people having age above 36 years show significant disagreement about adequacy of dam safety measures maybe because they have direct and previous experiences for dam failure and flash flood incidents.

These contrasting perceptions regarding dam safety measures calls for targeted policy interventions to address the concerns of groups viewing the adequacy of dam safety measures negatively. Policies should include local awareness campaigns on earthquake and flood risks in the region. Also, there is need to ensure fair water distribution among agricultural, industrial, and domestic users. For farmers, alternative water sources should be arranged in case of dam-related droughts or floods. Policies must be tailored for different groups for effective risk management, communication, and disaster preparedness. There should be inclusive decision-making involving representatives from different occupations and age groups.

CHAPTER 7

SUMMARY OF CONCLUSION

The main aim of this study was to investigate whether Ranjit Sagar Dam has induced diverse socio-economic impacts spatially (in upstream and downstream regions of its watershed) and temporally (during constructional phase and operational phase). The study also covers the distribution of resources and potential dam failure risks in Ranjit Sagar Dam Watershed as the socio-economic development of a dam's watershed is influenced by the optimum usage of available resources and eliminating the potential risks to the dam safety effectively. The results revealed significantly diverse association between demographic variables (occupation, age and education) and spatial-temporal socio-economic impacts, indicating that demographic variables play an important role in predicting the impacts of Ranjit Sagar Dam during constructional and operational phase in upstream and downstream regions. These finding aligns with earlier studies, such as those by (Fung et al.2019) and (Negi & Punetha, 2017) but also diverge from the results of these studies as they did not incorporate demographic variables and temporal factor to analyse the socio-economic impact of dams.

In the following sections, we will examine these findings in more detail, comparing them with existing research, exploring their theoretical implications, and considering their practical applications. We will also suggest directions for future research. The chapter is divided in following sections:

7.1 Main Findings and Discussion

7.2 Recommendations

7.3 Conclusion

7.1 Main Findings and Discussion

7.1.1 Physical Resource Base of Ranjit Sagar Dam watershed

To begin with, the present study explores the spatial distribution of physical resources in Ranjit Sagar Dam Watershed. This research identified several important aspects covering the topography, drainage system, soil types, geology, vegetation and Land Use

Land Cover of the study region. The study revealed that Ranjit Sagar Dam's watershed is characterized by steep slopes with severe soil erosion in upstream region, varied soil types with downstream soils more fertile, Dry Deciduous Scrub and Northern Mixed Dry Deciduous Forests are found along the river and stream banks, dendritic drainage pattern and seasonal fluctuations in water availability, composed of young Siwalik hills exposed to denudational processes, land use classes show a mix of agricultural and forest land with significant anthropogenic activity in the Ravi floodplain southwards of downstream region. All these factors have significant implications for water availability, erosion control, and overall watershed sustainability.

The topographical analysis revealed that the watershed has steep slopes in the upper reaches, contributing to rapid surface runoff and potential soil erosion. Similar trends have been observed in (Sharma, 2019), indicating a need for soil conservation measures. The watershed is predominantly composed of (young Siwalik rocks/loamy to silty soil texture), which influences water retention capacity and sediment yield. The high presence of loamy lithic and coarse loamy soils suggests vulnerability to erosion, aligning with findings from (Sharma, 2019). The watershed experiences significant seasonal variations, with peak flows occurring during the rainy season. This aligns with previous study (Jain et al.) , emphasizing the need for effective flood control measures. Land use analysis revealed extensive agricultural activities, built up and unplanned sand mining activity in the downstream region of dam's watershed, which may contribute to land degradation, environmental pollution and water quality deterioration as documented in studies by (Tripathi et al.2024). The combined impact of steep slopes, erosive soils, and indicates a high risk of sediment accumulation in the dam reservoir, potentially reducing storage capacity over time. Implementing sustainable watershed management strategies, such as afforestation and contour farming, could mitigate these effects. Moreover, the combined impact of extensive agricultural activity, built up expansion and quarrying activity in downstream region may degrade environment and water quality which suggest that managing land use practices and monitoring water quality is essential for overall sustainability of Ranjit Sagar dam watershed. The findings are consistent with those of (Kumar, 2018) who studied hydrobiological parameters of Ranjit Sagar Wetland and observed similar trends. Furthermore, Singh et al.2021 mentioned that major source of pollution into Ranjit Sagar Reservoir is landsliding, fishing and anthropogenic activities but deviates from our findings as they found that water quality of Ranjit Sagar wetland is good as compared to the other wetlands. Such a comparative study lacks in our research.

7.1.2 Analysis of Socio-Economic Impacts Induced by Ranjit Sagar Dam

The upstream and downstream regions of Ranjit Sagar Dam watershed experience a wide range of socio-economic impacts, both positive and negative, during constructional and operational phase of dams. Depending on factors such as the region's economic structure, demographic characteristics, and environmental conditions these impacts can vary significantly. In this study, we examine the socio-economic consequences of the Ranjit Sagar dam under the broad themes of Livelihood, Infrastructure and Community in both the upstream and downstream regions, focusing on aspects such as employment opportunities, education, Income level, and community well-being and how the different demographic groups perceive these impacts. Understanding these effects is essential for assessing the long-term viability of dam projects and ensuring that their advantages are fairly shared, ensuring minimal harm to vulnerable groups. First and foremost, this section, examines the demographic disparities between upstream and downstream region of Ranjit Sagar dam and watershed. Secondly, the influence of occupation and Age on the individual's opinions regarding socio-economic impacts of Ranjit Sagar Dam are discussed.

7.1.2.1 Demographic Disparities between Upstream and Downstream regions of Ranjit Sagar Dam

Comprehending these inequalities and imbalances is crucial, as they provide cognizance into the potential challenges and opportunities for each region as they traverse the socio-economic impacts of the dam. This research highlights significant educational, occupational and income disparities between the upstream and downstream regions of Ranjit Sagar Dam, revealing remarkable differences in literacy rates, occupational attainment and Income distribution as explained below:

- ***Educational Disparities between Upstream and Downstream Regions***

  One of the noteworthy disparities observed in this study is key differences in socio-economic indicators such as educational levels, occupational structure and Income level between respondents from the upstream and downstream regions. For inclusive, immediate and long term socio-economic regional development, in the vicinity of Ranjit Sagar Dam, evaluating and analysing these imbalances in demographic components have significant implications. Two significant findings in term of educational disparities are discussed below:

1. *More Illiterate individuals in the Downstream Region*

With 25% of respondents reporting that they are illiterate, the downstream region demonstrates a higher level of illiteracy as compared to the upstream region which shows a significantly lower illiteracy rate of 10%.

2. *Upstream Respondents have high level of Educational Attainment*

More than 50% upstream individuals have attained the secondary level of education as compared to the downstream region which reports Primary level as the predominant level of educational attainment by 42% of respondents. These findings differ from previous study by Wiejaczka et al. 2018 who analyzed the respondent's perceptions regarding Teesta Dam on the basis of Education level and Age only in upstream region and found that majority of the upstream respondents have attained primary level of education. While previous study has focused on educational level of Upstream region, we have compared the upstream and downstream regions in terms of educational level.

It is clear that the people living in downstream region of Ranjit Sagar Dam may have more notable obstacles to social mobility, economic development, their ability to adopt changed employment pattern and environmental conditions due to dam construction and capacity for community engagement. In contrast, high literacy rates and secondary level of education by majority of upstream respondents indicates that people residing upstream have more access to employment, better-paying jobs, overall quality of life, enhanced capacity to effectively engaged in community development projects, including dam construction and its socio-economic impacts. This significant gap in educational attainment is a crucial consideration for improving socio-economic outcomes in these communities and developing targeted policy recommendations.

- ***Disparities in Employment Status of Upstream and Downstream Regions***

The study reveals key differences in occupational pattern of both the regions with upstream areas being more focused on dam-related employment (38.9%) and government jobs (17.1%), while downstream areas exhibit a stronger reliance on farming (33.3%) as the primary livelihood. This suggests that the upstream area may have more direct involvement in dam-related activities, such as construction, maintenance, or operations, possibly due to proximity or specific regional investments in the dam industry and upstream areas have more government infrastructure or institutions, offering more employment opportunities in the public sector. The data reflects the downstream area's greater reliance on agriculture, likely due to fertile land or more suitable environmental conditions for farming, making it the primary livelihood for residents. In a similar manner, Smith (2024) raised the issue of gender-based employment disparities due to dam but diverges from our study as we have highlighted the region-based occupational imbalances rising due to dam construction study underscores the need for policies that address regional occupational imbalances caused by dam construction, ensuring equitable job opportunities and economic stability.

- ***Disparities in Income Level between Upstream and Downstream Regions***

There is a significant difference in the average monthly income between the upstream and downstream regions. In our study, the upstream region showed an average income of Rs. 33349.53 per month, while the downstream region had an average income of Rs.30,676.5 per month, a difference of Rs 2673.03. This disparity can be ascribed to several factors. The downstream region primarily relies on agriculture with more respondents have farming as their basic occupation that tend to have lower wage levels due to labour- intensive nature and unskilled work as compared to the upstream region where more respondents are dam employees, which typically offer better pay due to higher skill requirements and economies of scale.

The upstream region also benefits from better educational attainment and more literacy rate as compared to the downstream region where 25% respondents are illiterate indicating that upstream people may have more opportunities for better paying-jobs which increases economic activity and wage levels. In contrast, the downstream region has limited access to such jobs, which hampers economic growth. This income gap can have serious implications for the regions, including higher poverty levels in the downstream area and potential outmigration of workers seeking better opportunities in towns and cities. Further research is needed to explore the effectiveness of policies that could bridge this gap, such as improving education, promoting agricultural development, and attracting investment to the downstream region.

Our study found a significant income gap between the upstream and downstream regions, with the downstream area showing an average monthly income less than the upstream region. This does not align with previous research by Duflo & Pande (2007), who found that rural poverty reduces in downstream districts of dams as compared to upstream districts attributed to institutional favouritism. Additionally, our study supports the findings of Owusu et al. (2018) regarding the reduced incomes of downstream communities due to disrupted farming and fishing activities.

7.1.2.2 Diverse Perceptions of Demographic Groups in Upstream and Downstream Region

On comparing the impacts of Ranjit Sagar Dam on Livelihood, Infrastructure and community over space (Upstream and Downstream region) and Time (Construction and Operation phases of dam), we found contrasting sets of views across different demographic groups. The details are given below:

- **Impact on Livelihood, Infrastructure and Community**

Downstream Region (Constructional and Operational Phase)

Respondents generally believed that the downstream region experienced more negative impacts on infrastructure (except roads) and community during the operational phase of the dam. This may be because downstream areas often experience changes in water flow, changes in natural resources, potential flooding, and other environmental disruptions. These negative impacts can affect local infrastructure such as drainage systems, water quality, and public utilities, along with the social structure of the community (e.g., displacement or migration). Dam employees viewed positive impacts on livelihood during construction as well as operational phase of Ranjit Sagar Dam. These findings aligned with (Owusu et al.2017; Asamoah et al. 2020) who found similar trends in case of Bui dam and Kpong dam respectively.

Upstream Region (Constructional and Operational Phases):

Dam employees in the upstream region believed there were more positive impacts during both phases. They felt that infrastructure and the community benefited from employment opportunities, improved living standards, and development projects (e.g., roads, electricity). In contrast, other groups (such as farmers and business people) reported more negative impacts on livelihoods, infrastructure, and the community in the upstream region, particularly related to the displacement of people, changes in water availability for agriculture, and the loss of resources as also documented by Magsi et al. 2022 and Sabir et al.2017 in case of *Chotiari* and *Diamer Bhasha* Dams (Pakistan).This contrast reflects differing priorities—while dam employees may focus on immediate economic development, farmers and businesses focus on the longer-term sustainability and accessibility of natural resources.

In nutshell, Ranjit Sagar Dam has positively impacted livelihood, infrastructure and community as perceived by Dam employees in Upstream Region during both phases and negatively impacted all three components as perceived by farmers and other occupational groups.

All occupational groups in Downstream region perceived negative impacts on Infrastructure and Community during both phases. Only improved road infrastructure is viewed as positive impact of dam during operational phase. Dam employees have positive outlook regarding impact on livelihood during both phases. Furthermore, inadequate dam safety measures are another critical component viewed negatively by the farmer community in both regions.

Overall, Ranjit Sagar Dam has positive impacts on Livelihood for Dam employees of both regions and the dam has negatively impacted Community and Infrastructure in downstream region during both phases. These results are consistent with the findings of studies by (Mayer et al. 2022; Arantes et al.2023; Abdullah and Rahman,2021) who studied the spatial aspect of dam's impacts but didn't incorporate the temporal and demographic factors.

7.1.3 Evaluation of Dam Failure Risks and Dam Safety Measures

This section discusses the findings on potential dam failure risks due to hydrological and geo-tectonic factors. The results indicate that extreme flooding due to increased GLOF activity in dam's catchment, overtopping, and seismic-tectonic activities in the dam's watershed are primary concerns.

- ***Key Findings regarding Hydrological Risks***

Based on the analysis of previous dam failure case histories in India, the results indicate that dam has potential threat due to overtopping and dam's body may be the high-risk location where breach can initiate. These findings align with those of Zhang et al. 2016a that put forward similar observations for statistical analysis of previous dam failures globally. Moreover, our findings differ from those by Dhiman & Patra, 2019 who found that average breach width is an important factor in case of dam failures in India.

Further, the study revealed that increased incidents of GLOF in Ranjit Sagar Dam catchment due to climatic change may be another potential hydrological risk to the dam safety. Also, these results show consistency with those observed by Issac et al. 2024 who highlighted the need of including GLOF in assessing the inflow design flood and capacity of spillway in Ravi River Basin.

- ***Key Findings regarding Geo-Tectonic Risks***

The findings suggest that underlying Goran Fault close to the dam site poses a potential threat to Ranjit Sagar Dam integrity. The results are akin to those studied by Wieland, 2020 who stated that fault movement near dam site is a critical seismic hazard in most types of dams.

The study also demonstrated that presence of young alluvium along dam site and vulnerability of soils to Liquefaction during earthquake are potential risks raising concerns about structural stability of Ranjit Sagar Dam. The results are similar to those observed by Krinitzsky & Hynes, 2002 who studied the impact of Bhuj Earthquake on liquefiable alluvium beneath dams.

This discussion highlights the critical role of both hydrological and geo-tectonic factors in dam failure risks. Implementing advanced flood forecasting models and automated spillway controls can significantly reduce overtopping risks. Additionally, routine geotechnical surveys and seismic monitoring should be integrated into dam safety protocols.

- ***Key Findings regarding Respondents Perceptions on Adequacy of Dam Safety Measures***

  The analysis revealed that the opinions regarding adequacy of dam safety measures are significantly shaped by occupational groups with farmers expressed negative views regarding adequacy of dam safety measures taken by dam authorities and dam employees significantly believe that dam safety measures are adequate. The results are consistent with the study by Khanm et al.2023 who discussed the role of community perceptions for preparedness regarding dam failure flood risks but deviates from the study by Mehta et al.2020 who suggested the use of evidence-based risk communication strategy to improve community preparedness for dam failure risks.

7.2 Recommendations

Based on the insights drawn from our findings regarding spatial distribution of resources in Ranjit Sagar Dam watershed, potential failure risks to structural stability and integrity of Ranjit Sagar Dam and the interlinked socio-economic impacts, the contrasting views and experiences of dam employees, farmers, business people, and other community members regarding the impacts of dam construction and operation suggest the need for carefully designed policies that address the concerns and maximize the benefits for all stakeholders. The policy implications and recommendations based on these findings can be outlined as follows:

- **Suggestions regarding Erosion, Sedimentation, Water quality of Ranjit Sagar Dam Watershed**

  In order to control the soil erosion in areas of steep slopes and consequent sedimentation into the reservoir, promoting sustainable land and forest management is critical. To improve water quality downstream of dam strict pollution control measures should be adopted along with the conservation of riparian vegetation which helps to protect water quality. Further, unregulated quarrying activity in Ravi River floodplain may degrade the wildlife sanctuaries and biodiversity in the downstream region, unplanned expansion of built-up area calls for preventing illegal sand mining and sustainable land use respectively.

- **Suggestions Regarding Socio-Economic Disparities**

  To address the educational disparities: Targeted educational programs and Effective Community Engagement need to be prioritized especially in downstream region. This can be done by introducing educational initiatives aimed to improve literacy rates including adult education and vocational training program, using visual aids or oral communication about dams impacts so that capacity of local population to effectively understand and engage in dam -related economic activities and support long-term sustainable socio-economic development could be enhanced.

- **Balanced inter-regional development by addressing income inequality**

  To bridge the income gap of both the regions, policies promoting the Regional economic integration are to be focussed. Initiatives like supplying agricultural product from downstream region to the upstream region should be preferred. Also, providing better transport infrastructure and connectivity to both regions can enhance trade and tourism. Private agencies involved in dam industry should be encourage to invest in social program and infrastructure in downstream region. Also, setting up small and medium enterprises with targeted support of government such as subsidies or incentives for business in downstream region can increase the income level of people.

  These initiatives would be more effective if people are trained with technical and entrepreneurial skills for managing small businesses ensuring that workforce is better equipped to have higher-paying jobs.

- **To Address the Employment Disparities**

  For Upstream Areas (focused on dam-related employment and government jobs): As there is high percentage of people involved in dam-related employment, to enhance local workforce capabilities in dam operation and maintenance, offering targeted skill training programs would be beneficial along with promoting dam related tourism, green energy initiatives and sustainable dam operation practices to minimize impacts on environment and creating balance in region's workforce. Also, there is need to expand infrastructure (such as the number of government offices, educational institutions and healthcare facilities) in public sector services to improve quality of life for upstream residents and offer broader employment options.

For Downstream Areas (focused on farming):

As the downstream people has more reliance on agriculture, to ensure long-term sustainability agricultural innovation is required. So, it is imperative to introduce climate resilient crops or organic farming so as to increase productivity along with empowering local farmers by training programs and access to technology to reduce environmental impact. Furthermore, boosting agricultural infrastructure (storage facilities, transportation, access to markets, better irrigational facilities), encouraging diversified agriculture (agro-processing, renewable energy such as biomass and solar energy) could reduce dependency on one crop providing economic stability and thus increase income of farmers.

Both areas (upstream and downstream) can work towards long-term, resilient and sustainable economic development by addressing sector-specific needs and opportunities with downstream region needs exploring sustainable farming techniques and upstream region requires focusing on environmentally responsible dam operations. The shared responsibility of both regions for sustainable future could strengthen the overall regional economy while protecting local environment.

- **To Address the Diverse Socio-Economic Impacts of Ranjit Sagar Dam**

  Sustainable Livelihoods: As per our findings, constructional and operational phases of a dam are more likely to generate short term and long-term negative impacts on livelihoods, respectively, particularly on farmers and people from business background in both Upstream as well as downstream regions. It underscores the need for introducing sustainable livelihoods by supporting those whose livelihoods are threatened by the dam construction. This includes addressing the concerns of displaced communities and farmers whose land and water resources may be affected. Policies should prioritize creating alternative and diversified livelihood programs for displaced people and communities who may be negatively impacted by the dam. This could include training programs, support for new agricultural technique, assistance with innovative farming methods, or small business development projects catered to regional requirements could all fall under this category.

Fair Distribution of Costs and Benefits: The disparities in viewpoints between dam workers and other professional groups (such as farmers and businesspeople) emphasize how crucial it is to make sure that the advantages of the dam project are shared fairly, particularly with regard to community development and livelihood support. Farmers and businesspeople claim unfavourable effects, especially because of resource disruptions and displacement, while dam staff see positive results.

Compensation and Resettlement: Plans for equitable compensation and resettlement should be created for farmers and business owners who lose their land or experience resource disruptions. These plans need to be community-centred, taking into account local requirements and guaranteeing that those who have been resettled have access to resources that are on par with or greater than those that they currently have (e.g., land, water access). This would lessen the detrimental effects on their livelihoods over the long run.

Inclusionary Stakeholder Engagement: When making decisions, dam authorities should make sure that all occupational groups' opinions are taken into account. Specific local needs and grievances can be identified with the assistance of community advisory committees or consultative groups made up of farmers, businesspeople, dam personnel, and other stakeholders. Frequent consultations will increase openness and promote confidence in impacted communities.

◦ **Suggestions regarding Impact on Infrastructure and Community**

The detrimental effects on infrastructure and community, especially in the downstream area, point to the necessity of stronger social and environmental protections during the building and operation stages. To make sure that populations downstream are not negatively impacted, these could involve keeping an eye on changes in water quality, flood hazards, and ecological integrity.

Comprehensive Infrastructure Planning: To support both the short-term needs (housing, healthcare, and education) and the long-term needs (roads, water supply systems, and communication networks), comprehensive infrastructure development should be undertaken in both the upstream and downstream regions. Particular attention should be paid to minimizing any disturbances to the current infrastructure, especially in the downstream area where resource distribution and water flow changes are more likely to have a detrimental effect on infrastructure.

Community Health and Welfare Programs: Policies should incorporate programs like enhanced healthcare, flood resilience, and water quality management that are meant to promote the health and welfare of populations affected by the dam. These programs ought to be created with the unique difficulties that impacted populations confront in mind, especially those who live downstream and may be negatively impacted by changes in water quality.

- **Environmental and Social hazards**

  Careful management of environmental and social hazards is necessary during the operational phase, especially in the downstream region. In order to prevent long-term harm to the community, it is imperative that issues of water flow, environmental changes, and infrastructure development be addressed.

  Environmental Management Plans: It is crucial to create environmental management plans (EMPs) that take into account the cumulative consequences of building and operating dams. Strategies for addressing biodiversity loss, water supply variations, and local ecosystem changes that may affect communities upstream and downstream should be part of these plans. Achieving a balance between environmental sustainability and development should be the goal.

  Effective evaluations and Monitoring: During the dam's construction and operation, frequent social and environmental effect evaluations had to be conducted. Data on the dam's continuing impacts on nearby communities, infrastructure, and ecosystems will be available from these assessments. The community should be informed of the findings of transparent monitoring so that they can express concerns if the effects get worse.

- **Mitigation of Downstream Impact**

  Policies in the downstream area should concentrate on reducing adverse effects on flooding and water quality. To guarantee that the community's access to clean water and other resources is not compromised, this may entail making investments in flood control measures, water filtering systems, and monitoring systems. Programs for environmental monitoring should be put in place to assess the dam's effects throughout time and make sure that any negative impacts on populations or ecosystems are detected early.

- **To Address the Contrasting Perceptions regarding dam safety**

  Dam Safety: Farmers and Dam employees have contrasting views about dam safety shows that both groups have different level of concern and understanding which is essential for framing constructive policies. Following recommendations are put forward to address these diverse concerns and promote dam safety and community well-being:

  Community Engagement Program: Implementing such programs by enhancing education and communication regarding dam safety protocols, risk assessments and emergency preparedness plans are essential steps that should be taken by dam authorities.

  Inclusive Decision-Making: As farmers are more concerned about impact of dam safety on their livelihood, there is need to develop collaborative risk management that involve farmers in dam safety planning and emergency response strategies to ensure security of their livelihood in case of dam failure or flooding events.

  Improved Transparency and Enhancing the Understanding: To enhance the understanding of local communities about how to respond during dam related incident, regular safety drills and simulations should be conducted involving dam employees, farmers and other groups. Moreover, to build the trust of farmers in the measures taken to improve dam safety, the results of dam safety inspections, safety upgrades or any incidents should be shared publicly with improved transparency so that farmers and communities feel more certain about dam operations and related socio-economic impacts.

Effective Flood Risk Management: Farmers concern about inadequate dam safety indicates lack of effective flood risk management strategies. In this regard, there is need to establish flood mitigation infrastructure such as early warning system, levees and floodplain management to protect agricultural land.

Overall quality of life across both regions can be improved by implementing these strategies targeted for balanced approach to development fostering equal opportunities and benefits to everyone in both regions.

7.3 Conclusion

The policy implications and recommendations highlighted in present study emphasize the need for a balanced approach to dam construction and operation, taking into account the needs of all stakeholders. Ensuring that the benefits of the dam are widely shared while addressing the concerns of impacted communities—particularly those in the upstream and downstream regions—will be key to mitigating negative effects and promoting sustainable development.

So, it can be concluded that Ranjit Sagar Dam has relatively benefitted more those people who are residing in Upstream region than their counterparts residing in downstream region. Additionally, the dam has plethora of adverse impacts mostly during operational phase.

The present study concludes that Ranjit Sagar dam's socio-economic impacts vary with Demographic groups, Space and Time (Table 7.1). So, it's pertinent to mention here that building dams to manage water resources is a dynamic process that incorporates the interconnected webs of sustainability, climatic change, society, and the environment. The entire growth process started by dams can be derailed by a slight imbalance in any one of these four factors since they are so interconnected. The greatest need is for a new hydropower development model that can balance economic and social development with environmental preservation and resettlement (Sun et al. 2020).

Table 7.1

Ranjit Sagar Dam: Summary of Spatial, Temporal and Demographic Variations in Socio-Economic Impacts

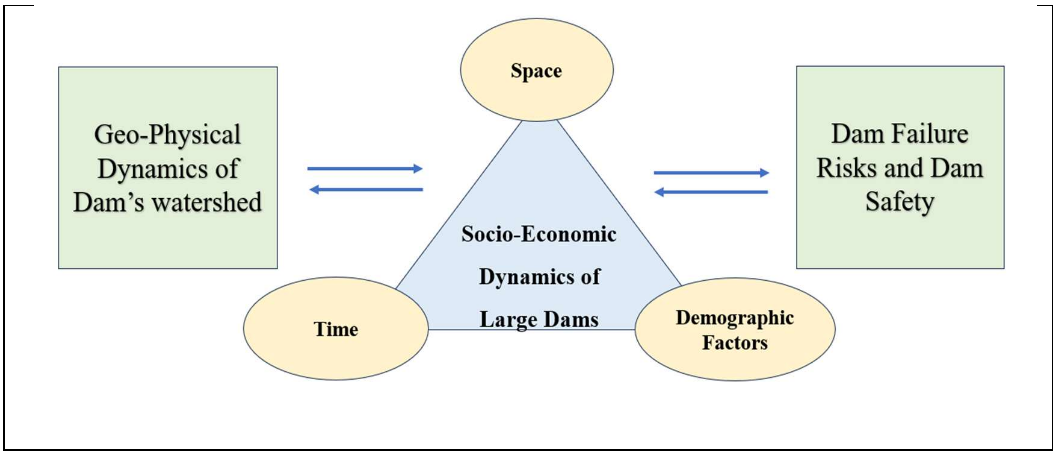
Components	Upstream Region	Downstream Region
Livelihood	Positive impact for dam employees during both phases	Positive impact for dam employees during both phases
Infrastructure	Positive impact for dam employees during operational phase	More negative impact during operational phase
Community	Negative impact	Negative impact
Dam safety measures	Inadequate as perceived by all occupational groups	Inadequate as perceived mostly by farmers
Income	Average monthly income is high	Average monthly income is comparatively low
Educational level	Comparatively less percentage of illiterates	More illiteracy
Employment status	More people in dam related jobs	High percentage of people with farming as source of livelihood

Thus, this study presents a new approach which integrates the socio-economic dynamics with Hydro-Geo-Physical features at watershed level. Socio-economic and geo-physical dynamics of large dams are not mutually exclusive but there exists two-way interplay between these factors. These mutual dynamics vary with space, time and demographic factors.

A new framework is proposed in this study as shown in Figure 7.1 which showcases that social sustainability of large dams should be integrated with the geo-physical sustainability of dam's watershed. Through equitable compensation, inclusive consultation, and robust environmental safeguards, it is possible to maximize the positive impacts of the dam while minimizing its adverse effects on livelihoods, infrastructure, and community well-being.

Fig. 7.1

Integrated Framework for Analysing Socio-Economic Impacts of Large Dams at Watershed level



Considering the interdisciplinary approach, planners and policymakers must also be involved. In addition to the elements listed above, there are some "innovative solutions" for mitigating the adverse effects of dams in general:

- To concentrate on creating innovative technologies that turn methane into electricity by capturing it from hydropower reservoirs before it enters the atmosphere (Hirsch 2007).
- Energy production is increased by placing solar panels on dam infrastructure (Rauf et al. 2020; Vella 2021).
- Methane emissions from dam's reservoir can be controlled by planting trees that can absorb methane emissions, such as spruce, pine, and others, as methane is a far more powerful greenhouse gas than CO2 (Yoneda 2013).
- Comprehensive statistical analysis of the morphometric parameters at the micro-watershed scale is necessary to control reservoir siltation (Singh & Singh 2020), and if sedimentation management starts within ten years of reservoir construction, the worst effects of sedimentation can be avoided (Anari et al. 2023).

- The agricultural productivity can be improved by using dam water for hydroponics and thus farmer communities can gain benefits (Sharma et al. 2019).
- To effectively distribute reservoir water for irrigation to various planting zones by using the "optimization model" (Alfaisl et al., 2023).
- Utilizing a variety of "Non-Revenue Water (the quantity of water generated and lost prior to reaching customers) Reduction Strategies" (Farouk et al., 2023). Water theft and other water losses (from leaks, bursts, overflow from water mains, and service connections) can be decreased in both developed and developing nations in this fashion.

The framework of optimal designs for the proper operation and maintenance of water resource projects affects many sectors, including food, energy supply, and water. Therefore, it is necessary to update and improve current curriculum connected to water resources (Singh, 2023). Thus, for sustainable dam development, all the planning and effective implementation should consider aligning the social aspects with the geophysical sustainability of the watershed and taking into account the space, time and demographic factors.

7.4 Future Scope of Research

The present study opens several avenues for future research:

- This study exemplifies and demonstrates the potential for broader research relevance for other large dam systems built in regions dominated by similar physical and hydrological conditions in dams' watershed. Future studies could use the Integrated Framework put forwarded in the present research to analyse the spatio-temporal dynamics of socio-economic impacts of big dams in integration with physical resources and dam failure risks at dam's watershed scale.
- Future research could examine other dams lying upstream and downstream of Ranjit Sagar dam along the Ravi River Basin, taking into account their distinct traits and difficulties. A more comprehensive understanding of how these water structures affect socio-economics of Ravi River Basin may be achieved through comparative analysis.

- Conducting more frequent and detailed analyses of water quality and water supply in downstream region of Ranjit Sagar Dam would offer a more sophisticated comprehension of the dynamics pertaining to causes of poor water quality as perceived by downstream communities and adoption of measures to improve water quality.
- Working together with specialists in a variety of disciplines, including ecology, sociology, and hydrology, could improve the study by adding a more comprehensive viewpoint. Multidisciplinary methods can reveal intricate connections and interactions influencing the dynamics of large dams.
- Including perspectives from other stakeholders, such as governments, non-governmental organizations, and industries, can provide a more thorough understanding of Ranjit Sagar Dam sustainability issues. A comprehensive understanding of long-term sustainability concerns and implementing initiatives can lead to more effective policies and action plans.
- A thorough examination of how climate change may affect failure risk to dams in Ravi River Basin in general and Ranjit Sagar Dam in particular would improve the understanding of adaptive risk management approaches. This could involve evaluating shifts in hydrological patterns, biodiversity, and ecosystem services.
- Furthermore, future studies could investigate changes in temperature, precipitation patterns, and their effects on the ecosystem and communities in Ranjit Sagar Dam Watershed. Understanding geographical interactions could inform adaptive conservation approaches in response to environmental shifts.
- Explore cutting-edge technologies and techniques, such as remote sensing and GIS, to enable continuous tracking and mapping of dam's socio-economic, environmental and failure impacts. These tools will improve data precision and facilitate informed decision-making.
- Examine the hydro-geographical dynamics of Ranjit Sagar Dam, focusing on changes in water flow, sedimentation trends, and hydrological interactions. Gaining insight into spatial and temporal variations is crucial for effective watershed management and conservation planning, which could inform future research.

- Gaining insight into the dynamics of community involvement and the factors that affect dam failure risk management can help shape the development of community-based risk preparedness strategies.
- A closer examination of the effectiveness and challenges of community engagement in risk management associated with failure of dam projects would yield valuable insights.

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Annexure 1.1

Section A: APPENDIX

A. Questionnaire: SPATIO–TEMPORAL ANALYSIS OF SOCIO-ECONOMIC IMPACTS INDUCED BY BIG DAMS: A CASE STUDY OF RANJIT SAGAR DAM

This questionnaire comprises background information and both quantitative and qualitative questions grouped into four sections. Section A addresses opinion of people on impacts during dam construction. Section B explores socio-economic impacts of Ranjit Sagar Dam during Operational phase. Section C examine the impacts on Dam safety. Section D measure resettlement plan implemented in the area and section.

BACKGROUND INFORMATION (Tick the most appropriate)

(a) Gender:

Male		Female	

(b) Age (Years):

10-15		16-20		21-25		26-30		31-35
36-40		41-45		46-50		51-55		Above 55

(c) Marital status:

Married		Unmarried	

(d) Family size (Numbers):

1-2		3-4		5-6		7-8		9-10		Above 10	

(e) Educational level:

Illiterate		Primary		Secondary		Tertiary		University	

(f) Occupation:

Farmer		Business Man		Civil Servant		Other job		No job	

(g) Monthly Income (In Rupee):

Below 10000		10000-20000		20000-30000		30000-40000		40000-50000		Above 50000	

SECTION A

What were the socio-economic impacts during dam construction in your area?

(I) Impact on Community

Yes		No	

If yes, how did it impact you?

	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
1. Increased Mental Health Issues					
2. Change in social system					
3. Burden on Resources					
4. Increased Conflicts					

(II) Agricultural/ Land Use change

Yes		No	

If yes, how did it impact you?

	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
1. Inundation of agricultural land and change in cropping pattern, decreased agricultural production					

(III) Livelihood changes

Yes		No	

If yes, how did it impact you?

	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
1. Farming to labor					

2. Farming to Business					
3. Got a job in any office of Dam					
4. Increased interest in Govt.jobs					
5. Others specify……………					

(IV) Impact on Infrastructure

Yes		No	

If yes, how did it impact your area?

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**
1.Loss of Roads, Schools, Hospitals, Houses, Cultural Monuments					
2. Loss of Business establishments and Govt. Buildings					

SECTION B

What are the socio-economic impacts during dam operational phase in your area?

(I) Impact on Community

Yes		No	

If yes, how it impacts you?

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**
1. Access to Sand Mining					
2. Access to Fishing					

(II) Livelihood

If yes, how it impacts you?

Yes		No	

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**
1. Increased employment in your area					
2. Most of the people employed in dam are outsiders					
3. Business Flourished					
4. Increase in Income and decrease in poverty					

(III) Infrastructural Changes

If yes, how did it impact you?

Yes		No	

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**
1. Improved roads and easy access to basic facilities					
2. Improved Drinking Water Facilities					
3. New Schools and Colleges					

SECTION C

(IV) Risks of Dam Failure /Flooding

Yes		No	

If yes, how it impacts you?

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**
1, Increase in Occurrence of flooding					
2. Adequate safety measures in case of dam failure and flooding					

SECTION D

Give your dichotomous response to the following questions:

	Yes	**No**
Was a proper resettlement followed by government for Displaced people?		
If yes, which of the following options were adopted		
Resettled in well Furnished Colonies		
Were provided with basic infrastructure (Water, Health, Education, Markets)		
Alternative agricultural land provided to people lost their lands.		
Did all people get fair and timely compensation		
Corruption during Compensation		

Thanks for participating and sharing your views and experiences.

(Nidhi Jasrotia)