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Study the Socio-Economic Dynamics of Farming Communities Practicing Agroforestry in upstream Catchment area of Gobind Sagar Reservoir

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ABSTRACT

The present investigation aimed to explore the socio-economic transformations experienced by farming communities under the influence of the nearby water reservoir. The socio-economic dynamics of 375 households across 25 villages in upstream catchment area of the Gobind Sagar Reservoir in Bilaspur district, Himachal Pradesh, were examined to assess the influence of reservoir proximity on agroforestry adoption and livelihoods. Households were grouped into seven distance classes (D1 = 0-2 km, D2 = 2-4 km, D3 = 4-6 km, D4 = 6-8 km, D5 = 8-10 km, D6 = 10-12 km, and D7 = 12-14 km) at 2 km intervals. The highest number of households was in D4 (372) and D5 (361), with family sizes ranging from 5.5 to 6.5 members. D4 also had the largest population (911 males, 883 females), while literacy peaked at 80.67% in D6. Households in D1 held the largest land (1.92 ha) and cultivated land (1.25 ha), whereas fodder consumption was highest in D5 (70.56 kg day^{-1} $household^{-1}$) and D4 (70.17 kg day^{-1} $household^{-1}$). Fuelwood use was greater among households near the reservoir. Agroforestry knowledge was highest in wider distance classes i.e. D7 and D5 (42.50%), compared to closer distance classes like D1 (30.67%) and D2 (30.33%). Positive correlations were found between cultivated land and *ghasni* (grassland), and between livestock population and fodder use, while agroforestry knowledge negatively correlated with fuelwood consumption. These findings suggest that reservoir proximity influences landholding, resource use, and agroforestry practices, shaping household adaptation strategies and socio-economic outcomes. The findings of this study can be utilized to design location-specific agroforestry and livelihood enhancement programs for communities influenced by water reservoirs.

1 | INTRODUCTION

The construction of large dams significantly impacts the socioeconomic situations of farming communities in its upstream catchment areas and downstream areas (Shi *et al.,* 2019; Liu *et al.,* 2023). These infrastructures provide crucial irrigation resources, which can enhance agricultural productivity and lead to more stable crop yields. Increased access to water allows farmers to diversify their crop patterns and engage in multiple cropping cycles, thereby improving food security and increasing household incomes (Sarvade *et al.,* 2014; Wable *et al.,* 2021; Rajkhowa, 2024). Additionally, the presence of a dam often fosters ancillary economic activities, such as transportation and agro-processing, which create job opportunities and contribute to local economic growth (Ampadu *et al.,* 2015). However, these benefits can be unevenly distributed, leading to income disparities within communities, especially if wealthier farmers or landowners gain more access to resources compared to marginal and smallholder farmers.

On the flip side, the socio-economic dynamics of these communities can also be adversely affected. The displacement caused by dam construction can disrupt traditional livelihoods and displace entire communities, leading to loss of agricultural land and local cultural heritage (Huang *et al.,* 2018). Moreover, the influx of external labour and capital can alter social structures, potentially undermining social cohesion and traditional practices (Krammer *et al.,* 2023). Environmental changes resulting from dam operations, such as altered water flow and sedimentation patterns, can negatively impact local ecosystems, further challenging the livelihoods of farming communities that depend on natural resources (Foudi *et al.,* 2023). Therefore, while big dams can offer substantial benefits for agricultural development, careful consideration of their socio-economic consequences is essential to ensure equitable growth and the sustainable management of resources in upstream catchment areas (Strobl and Strobl, 2011).

The socio-economic conditions of communities around the Gobind Sagar Reservoir are closely tied to the availability of critical resources such as water, soil, and vegetation. These factors not only affect agricultural productivity but also contribute to the overall well-being of local residents (Parizanganesh *et al.,* 2008). In the hilly terrain of the upstream catchment area, water scarcity presents significant challenges, directly impacting soil health, vegetation, and the socio-economic conditions of the populace (Dwivedi *et al.,* 2007; Su *et al.,* 2012).

Agriculture and cattle rearing serve as the primary livelihoods for these communities; however, limited water resources constrain agricultural yields, leading to changes in land use and natural vegetation (Sarvade *et al.,* 2016b; Ingrao *et al.,* 2023). Education, transport, and employment significantly influence land-use transformations, with educated farmers often seeking to optimize land productivity by utilizing knowledge from government initiatives and research institutions (Lovell, 2010). The size of landholdings and human resources further shape agricultural practices, with smaller landowners typically opting to plant multi-purpose trees (MPTs) to enhance their income. In contrast, traditional practices often involve retaining MPTs within farm boundaries for long-term benefits (Nair, 1989; Sarvade *et al.,* 2020). Agroforestry, which integrates trees with crops and livestock, emerges as a crucial system for promoting socio-economic development in these regions, providing avenues for improved livelihoods and environmental sustainability (Nair, 1989; Nair, 2011). These types of studies are limited but very useful for the planning of well-being of the farming community residing nearby dam sites. Therefore, the present investigation was carried out to study the impact of constructing big dams on socio-economic situation of farming communities situated in upstream catchment area of the water reservoir with the following objectives: 1. To analyze the influence of reservoir proximity on the socio-economic status and livelihood patterns of farming communities residing around the Gobind Sagar Reservoir. 2. To assess the variations in landholding size, resource utilization, and extent of agroforestry adoption across different distance zones from the reservoir. 3. To identify and establish relationships among key socio-economic parameters affecting household adaptation strategies and resource management practices in the region.

HIGHLIGHTS

- Examined socio-economic variations among villages at different distances from the Gobind Sagar Reservoir in Himachal Pradesh
- Reservoir proximity influenced household characteristics , resource dependence and livelihood diversification.
- Near-reservoir communities relied more on natural resources, while distant ones showed greater adoption of agroforestry.
- Results call for location-speciifc agroforestry and livelihood interventions to enhance community resilience

2 | MATERIALS AND METHODS

2.1 | Study Area

The study was conducted in the upstream catchment area of the Gobind Sagar Reservoir, which is situated on the 'Sutlej River' in the Bilaspur district of Himachal Pradesh. The Gobind Sagar Dam, also known as the Bhakra Dam, is one of the largest gravity dams in India, constructed across the Sutlej River. Commissioned in 1963, the dam stands about 226-meter-high and stretches approximately 518 meter in length, creating a vast reservoir with a storage capacity of around 9.34 billion cubic meters. The reservoir extends over 90 kilometers in length and covers an area of nearly 170 square kilometers, serving multiple purposes including hydroelectric power generation, irrigation, and fisheries, while also shaping the socio-economic landscape of surrounding rural communities. This region spans an area of 1,167 km^2, representing 2.1% of the state's total geographical expanse. The elevation in this area varies significantly, ranging from 290 m to 1,980 m above mean sea level, with a substantial portion of the district lying below 650 m. The geographical coordinates for this site are approximately 31° 12' 30" to 31° 35' 45" N and 76° 23' 45" to 76° 55' 40" E (Sarvade *et al.,* 2016a).

2.2 | Sampling Method

A multistage stratified random sampling design was employed to identify communities involved in agroforestry, which were regarded as the basic study units for this research. This method blended purposive and stratified random sampling techniques, ensuring a detailed and representative selection of participants (van Hoeven et al., 2015). A total of 25 villages were included in the study, with 15 households randomly selected from each village. To minimize bias in household selection, we enlisted the help of a local guide who assisted in identifying households that fit the specified farmer categories within each village. These study sites were distributed randomly across seven concentric rings (distance classes), each 2-kilometer-wide, in upstream catchment area of the Gobind Sagar Reservoir (*Table 1 and Fig. 1*).

Households serve as the primary decision-making units in cultivating fodder, fuelwood, and fruit trees on their own lands, whether through natural growth or intentional planting. To gather primary data on various socio-economic attributes, face-to-face interviews were conducted with the heads of households in the chosen villages using a pre-tested questionnaire (online available) (Marshall 2005). The selection of these villages was informed by secondary data from the 2011 Census (Census, 2011).

TABLE 1 Details of the study sites

Distance classes	Study sites	Latitude and Longitude (Degree, decimal, seconds)
D1	2-Jai Shri Devi	31˚25'27.2"N and 76˚29'57.3"E
	3-Badgaon	31˚26'43.9"N and 76˚29'53.5"E
	5-Jaddu	31˚22'22.1"N and 76˚33'25.0"E
	6-Malroan	31˚19'22.5"N and 76˚35'42.6"E
	19-Fugogh	31˚20'28.8"N and 76˚38'47.86"E
	13-Dhanola	31˚16'28.20"N and 76˚37'58.4"E
D2	9-Paploh	31˚18'34.9"N and 76˚37'55.5"E
	12-Kharli	31˚16'02.8"N and 76˚39'19.9"E
	11-Kukrehar	31˚16'25.1"N and 76˚39'43.3"E
	10-Silwin	31˚18'21.4"N and 76˚39'06.7"E
	7-Tihri	31˚21'15.1"N and 76˚35'07.4"E
	8-Jhunjnu	31˚20'03.2"N and 76˚36'21.3"E
D3	1-Jol	31˚24'58.2"N and 76˚32'23.5"E
	4-Gangloh	31˚23'58.5"N and 76˚33'11.0"E
	18-Baloh	31˚20'43.91"N and 76˚43'22.72"E
D4	14-Beharan	31˚22'41.50"N and 76˚38'26.80"E
	22-Kuthera	31˚23'26.70"N and 76˚36'02.70"E
	24-Talai	31˚27'17.95"N and 76˚31'25.31"E
D5	15-Ser	31˚22'49.0"N and 76˚40'24.70"E
	25-Jhabola	31˚27'0.20"N and 76˚32'13.50"E
D6	20-Balsina	31˚22'15.99"N and 76˚43'7.726"E
	23-Gujrera	31˚25'09.40"N and 76˚34'15.30"E
	21-Malari	31˚24'46.00"N and 76˚36'32.20"E
D7	16-Dhroti	31˚24'47.7"N and 76˚39'16.30"E
	17-Singaswin	31˚25'12.60"N and 76˚37'38.30"E

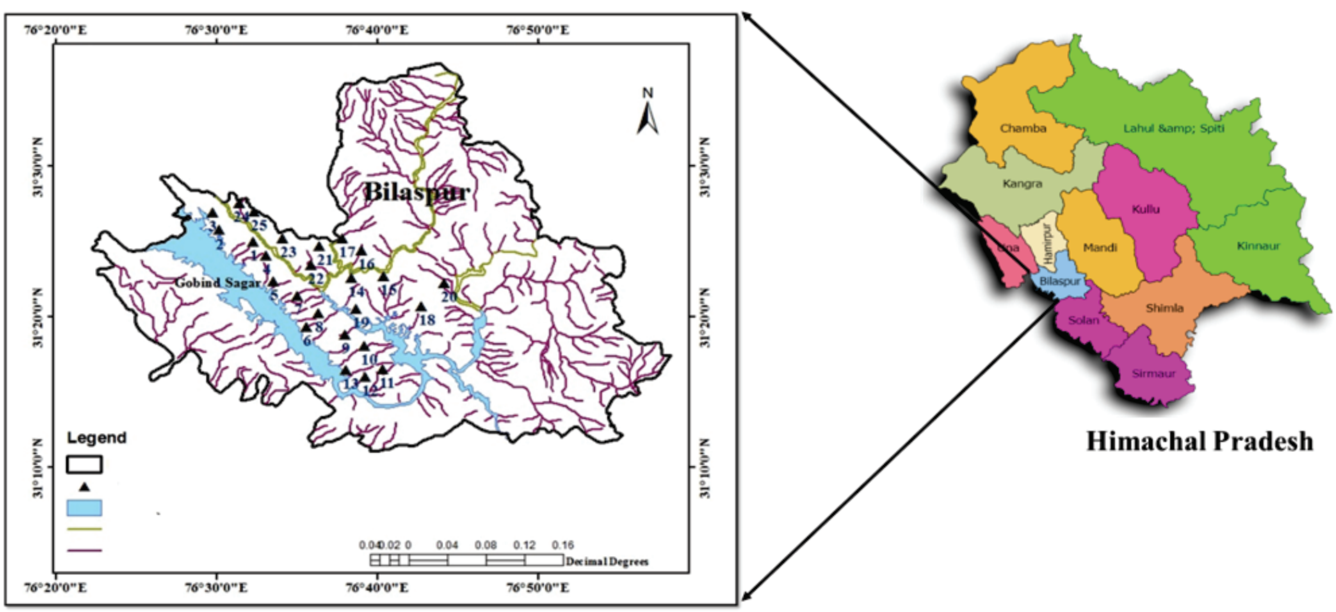

FIGURE 1 Study sites selected in upstream catchment area of Gobind Sagar reservoir (Source : Sarvade *et al.*, 2016b)

2.3 | Statistical Analysis

Descriptive statistics, encompassing mean values and standard deviations at a 95% confidence interval, were computed in accordance with the procedures described by Lindman (1992). To ensure greater precision and conformity with modern social survey standards, the analytical framework was further refined by incorporating the updated methodological recommendations of Dillman *et al.* (2014). Z- test was carried out for percent data and t-test for demography, literacy, land use, livestock at 0.05 level of probability. The Pearson correlation between different socioeconomic variables was carried out at 0.01 & 0.05 level of probability. All analysis was carried out by using SPSS (Version 23) statistical software package (IBM Corp, 2015).

3 | RESULTS AND DISCUSSION

3.1 | Demographic features of the farm families

An analysis of the demographic data of farming families from villages located around the Gobind Sagar reservoir reveals notable trends in household distribution based on proximity to the water source. Table 2 indicates that households are most concentrated in equidistant areas from the reservoir, particularly in zones D4 (average of 371.67 HH) and D5 (360.50 HH). In contrast, areas closer or further away, such as D3 (149.33), D6 (140.67), D1 (88), D7 (87.50), and D2 (60.17), exhibit significantly lower household counts.

The demographic analysis reveals that the highest population figures were observed at distance D4, with a total of 1,794 individuals - comprising 911 males and 883 females. Interestingly, the sex ratio in households located near the Gobind Sagar reservoir indicated a slight male predominance, with ratios of 935.37 at D1 and 935.22 at D2. In contrast, areas further from the reservoir, such as D3 (1,056.58), D6 (1,031.95), D5 (1,026.22), and D7 (1,012.32), reported higher female populations than male, suggesting a shift in gender dynamics.

The demographic profile of farm families surrounding the Gobind Sagar reservoir presents a nuanced understanding of rural livelihoods shaped by both ecological and infrastructural variables. The evident disparity in development indicators among the study sites appears to stem from the varying degrees of influence exerted by the reservoir, which has indirectly shaped access to essential services like transportation, education, healthcare, irrigation, and market linkages, thereby redefining the socio-economic landscape of the surrounding communities. This aligns with the perspectives of Adesina and Chianu (2002) and Neupane and Thapa (2001), who underscored the catalytic role of infrastructure in shaping household dynamics in rural landscapes. Chavez *et al.* (2013) further supported this, noting that proximity to essential services strongly influences demographic composition and settlement stability.

Family size, a critical demographic marker, exhibited only marginal variation across the study sites, averaging between 5.50 to 6.50 members. Interestingly, the largest average family size was recorded in D5, suggesting that variations in household structures are not random but are strongly shaped by local socio-economic dynamics. Factors such as income levels, livelihood options, educational opportunities, and resource accessibility collectively influence how families are organized. Hence, the composition and functioning of households reflect the broader socio-economic context in which they exist. These trends are consistent with the findings of Masoodi (2010) and Sharma (2012) in Himachal Pradesh, where educational attainment and occupational shifts were linked to family size. Notably, Joshi (2011) and Nisha (2013) also observed similar household sizes in different agro-ecological zones of the region. The Bundelkhand region, with much larger household sizes (Kareemulla *et al.,* 2002), and smaller average sizes in Chinese villages (Demurger and Martin, 2010), reflect the diversity of family structures shaped by regional socio-economic and cultural contexts.

The observed improvements in sex ratios across certain sites point towards a progressive shift in societal attitudes concerning gender roles. Vepa (2007) and Bhattacharya (2012) emphasized such evolving perceptions as instrumental in fostering gender parity, supported by national-level trends documented by Echavarri and Ezcurra (2010). These findings indicate that improvements in socio-economic conditions, coupled with targeted advocacy, education, and awareness initiatives, have started to produce tangible demographic benefits for women, reflecting their enhanced participation and empowerment within the community.

3.2 | Literacy Rate

The literacy rates among residents of villages surrounding the Gobind Sagar reservoir, as illustrated in Table 3, reveal that educational attainment is highest in areas located equidistant from the reservoir, particularly at distances D5 (8-10 km) and D4 (6-8 km). These villages outperformed others in terms of primary, middle, high school, intermediate, graduate, and postgraduate education levels. Notably, D5 recorded the highest number of individuals with secondary education, yet it also had the highest illiteracy rate, with 540 illiterate individuals, followed closely by D4, D3, D6, D1, D7, and D2. The overall literacy rate across surveyed households exhibited no distinct pattern related to proximity to the reservoir. The highest literacy rate was found in D6 at 80.67%, while D3 had the lowest at 68.67%.

Literacy levels in the study area also provide insights into intergenerational educational shifts. A notable share of illiterate individuals was observed among the older population, while younger generations exhibited higher literacy levels, likely reflecting both expanded access to education and the indirect effects of the reservoir, which, by improving local economic conditions, enabled families to invest more in schooling and educational opportunities. This positive trend is likely linked to increased household income, better access to schools, and changing aspirations, echoing the assertions of Archer *et al.* (2010), Hanasaki *et al.* (2013), and Singh (2014). The influence of household economic status on children's educational attainment, as described by Chevalier *et al.* (2013), reinforces the need for holistic approaches that integrate economic development with educational policies.

3.3 | Land Management

The land use patterns among farmers in the upstream catchment area of the Gobind Sagar reservoir, as detailed in Table 4, reveal varying land holdings across different distance classes. Average land holdings ranged from 1.29 ha to 1.92 ha, with the largest holdings found in D1 (1.92 ha) and D3 (1.82 ha), while smaller holdings were noted in D2 (1.29 ha) and D4 (1.30 ha). Interestingly, the amount of land leased for cultivation and other purposes was greatest in the distance classes farther from the reservoir, particularly in D7 (0.09 ha) and D3 (0.06 ha). In contrast, the least leased land was found in the proximity of the reservoir, specifically D1 (0.02 ha) and D2 (0.005 ha). The analysis indicated that farmers in D3 also reported the highest irrigated land (0.14 ha), whereas D1 had the most un-irrigated land, totaling 1.85 ha. Additionally, D1 farmers maintained the largest cultivated area (1.25 ha) compared to those in other distance classes. The areas dedicated to orchards (0.06 ha) and *ghasni* (0.50 ha), (it is a local term for a patch of land covered with grass, known generally as a grassland) were most prominent in D5 and D3, respectively. Barren land was most prevalent in D6 (0.19 ha), followed by D1 (0.17 ha) and D3 (0.14 ha).

The patterns of land management around the reservoir reflect the combined influence of population pressures, socio-economic demands, policy regulations, and the pursuit of environmental sustainability, illustrating how communities adapt their practices in response to both ecological and livelihood challenges. The encroachment of land for infrastructure and education facilities, coupled with policy-induced land use regulations, has transformed traditional practices, supporting findings by Jayakumar *et al.* (2013) and Garg *et al.* (2020). A move towards climate-adaptive and resource-conserving strategies is evident, emphasizing the need for inclusive land-use planning to safeguard both ecological and human systems.

TABLE 2 Demography of villages at different distance classes from reservoir

Distance classes	Demograhpy					
	Average number of households/ villages	Average family size/ household	Population/ village	Male/ village	Female/ village	Sex ratio
D1	88.00[c]	5.67[a]	439.33[c]	227.00[c]	212.33[c]	935.37[b]
D2	60.17[c]	6.17[a]	303.50[d]	156.83[d]	146.67[d]	935.22[b]
D3	149.33[b]	6.00[a]	751.33[b]	365.33[b]	386.00[b]	1056.58[a]
D4	371.67[a]	5.67[a]	1794.33[a]	911.00[a]	883.33[a]	969.63[ab]
D5	360.50[a]	6.50[a]	1738.50[a]	858.00[a]	880.50[a]	1026.22[a]
D6	140.67[b]	6.00[a]	678.67[b]	334.00[b]	344.67[b]	1031.95[a]
D7	87.50[c]	5.50[a]	408.50[c]	203.00[c]	205.50[c]	1012.32[a]
Mean	179.69	5.93[a]	873.45	436.45	437	995.33[ab]
P Value	0.031	0.33	0.027	0.023	0.022	0.041

Different upper case small letter showed statistical difference in different distance classes using t-test at 0.05 probability level.

3.4 | Livestock population, consumption of fodder and fuelwood

The data presented in Table 5 and Appendix I reveal notable variations in livestock numbers and the consumption of fodder and fuelwood among farmers residing at different distances from the Gobind Sagar reservoir. At a distance of D5, the average number of cows per household reached its peak at 2.5, representing 38.46% of the total livestock population. However, the number of cows tended to decrease with increasing distance from the reservoir: D4 (2.33), D6 (2.00), D2 (1.50), D7 (1.50), D3 (1.33), and D1 (1.17). In contrast, the average number of bullocks was highest at D1 (1.50), while the goat population was most abundant in D6 (3.33). Sheep were predominantly found at D1 and D3, each recording an average of 1.00 sheep per household. Buffalo numbers were consistent across several distances, with an average of 1.00 at D3, D5, D6, and D7. Overall, total livestock per household ranged from 5.50 at D7 to 8.00 at D3. Fodder consumption varied significantly across distances, ranging from 42.28 to 70.56 kg per day. The highest fodder intake was observed in areas further from the reservoir, such as D5 (70.56 kg) and D4 (70.17 kg), with consumption decreasing as the distance to the reservoir shortened: D6 (63.34 kg), D2 (56.93 kg), D7 (51.56 kg), D3 (47.11 kg), and D1 (42.28 kg). Conversely, fuelwood consumption was highest in households closer to the reservoir, particularly at D2 (21.31 kg) and D1 (20.46 kg), with lower consumption noted at greater distances: D4 (19.63 kg), D5 (19.50 kg), D3 (19.18 kg), D7 (17.17 kg), and D6 (16.52 kg).

Livestock dynamics emerged as another crucial indicator of rural sustainability. The correlation between fodder resource availability and livestock numbers was apparent across sites, affirming observations by Dwivedi *et al.* (2007), Radha and Kumar (2022), and Sharma and Omena (2024). Consumption patterns for fuelwood and fodder also varied with proximity to urban centers, where modernization and access to cleaner energy alternatives gradually shift households away from traditional biomass dependency (Arya *et al.,* 2012; Singh *et al.,* 2010; Hussain *et al.,* 2017). This shift in energy use reflects the gradual transformation of rural economies, increasingly shaped by connections to urban markets, infrastructure, and lifestyle influences.

3.5 | Sources of employment and income

The data presented in Table 6 illustrates the contribution of various income sources to household earnings as distances from the Gobind Sagar reservoir change. Agriculture accounted for about 50% of total household income. This was complemented by other income sources: small businesses and private jobs contributed 27.40%, dairy farming provided 14.90%, government jobs contributed 4.90%, and fishery activities made up 2.70%. Notably, households in the D1 distance class exhibited a higher reliance on agriculture, which constituted 56% of their income, along with contributions from dairy (19.30%), fishery (7%), and government jobs (6.30%). In contrast, households in D7 showed a greater reliance on alternative income sources, with small businesses and private jobs contributing significantly (45%).

The reservoir's role as an economic catalyst was notable, with diverse livelihood strategies emerging in its vicinity. From agriculture to fisheries, tourism, and allied sectors, the resource base created new opportunities for income generation, which not only reduced economic vulnerability but also bolstered resilience (Birthal *et al.,* 2014; Vatta and Budhiraja, 2020). These transformations validate the assertion that water bodies, if sustainably managed, can serve as engines of rural development. The present study's findings are consistent with earlier research emphasizing the socio-economic consequences of dam construction and management on local communities. Ampadu *et al.* (2015) reported that the establishment of dams in Ghana significantly influenced the livelihoods of downstream populations by altering water availability, agricultural productivity, and income patterns. Similarly, Huang *et al.* (2018) highlighted that dam-induced changes in hydrological regimes often lead to shifts in land use, resource accessibility, and settlement structures, affecting the overall socio-economic resilience of rural households. These observations reinforce the need for inclusive development planning and participatory water resource governance to ensure that the benefits of dam projects are equitably distributed while minimizing adverse impacts on local economies and social well-being.

TABLE 3 Literacy of people at different distance classes from reservoir

Distance classes	Qualification							Literacy (%)
	Primary	Middle	High School	Intermediate	Graduate	Post graduate	Illiterate	
	Number of people (Mean)							
D1	101.17^{d}	102.83^{c}	94.17^{e}	43.17^{d}	8.83^{cd}	3.00^{d}	123.00^{d}	75.33^{a}
D2	79.50^{e}	57.17^{de}	87.50^{e}	39.67^{d}	17.67^{c}	0.00	77.83^{e}	78.17^{a}
D3	187.00^{c}	211.67^{b}	130.33^{d}	47.33^{d}	10.33^{cd}	0.00	275.00^{c}	68.67^{b}
D4	346.67^{a}	304.00^{a}	480.67^{b}	401.67^{a}	84.67^{a}	161.33^{a}	442.00^{b}	78.67^{a}
D5	368.50^{a}	310.50^{a}	631.00^{a}	331.50^{b}	50.00^{b}	30.50^{c}	540.00^{a}	75.50^{a}
D6	213.33^{b}	79.33^{d}	200.67^{c}	102.33^{c}	18.33^{c}	71.00^{b}	155.33^{d}	80.67^{a}
D7	134.50^{d}	25.00^{e}	115.50^{d}	55.50^{d}	14.00^{c}	25.00^{c}	117.00^{d}	76.00^{a}
Mean	204.38	155.79	248.55	145.88	29.12	41.55	247.17	76.14
P Value	0.026	0.022	0.021	0.034	0.037	0.025	0.024	0.041

*Different upper case small letter showed statistical difference in different distance classes using t-test at 0.05 probability level; *Z-test used at 0.05.*

3.6 | Knowledge of Agroforestry

The assessment of households regarding their knowledge of agroforestry and its adoption, as detailed in Tables 7, reveals significant insights into the understanding of agroforestry systems among different communities. Households located arther from the Gobind Sagar reservoir, specifically in D7 and D5, demonstrated a higher level of knowledge about agroforestry, with approximately 42.50% of these households being informed about various agroforestry practices. In contrast, households closer to the reservoir, such as those in D1 (30.67%) and D2 (30.33%), exhibited lower awareness levels.

Awareness and knowledge of agroforestry practices were widespread among the surveyed families, demonstrating that it is not an alien concept but rather a historically ingrained practice supported by modern institutional interventions. Government and NGO-led training and extension programs have played an instrumental role in disseminating agroforestry knowledge (Dhyani, 2009; Berry *et al.,* 2021). Such interventions bridge traditional wisdom with scientific innovations, promoting long-term sustainability and improved livelihoods.

TABLE 4 Land management at different classes from reservoir

Distance classes	Land use per house hold (ha HH^{-1})							
	Average land owned	Leased	Irrigated	Un-Irrigated	Cultivated*	Orchard	Ghasni (grassland)	Barren
D1	$1.917^{a} \pm 0.60$	0.020^{a}	0.097^{b}	1.848^{a}	1.25^{a} (64.44)	0.03^{a} (1.29)	0.47^{a} (24.17)	0.17^{a} (8.78)
D2	$1.292^{a} \pm 0.35$	0.005^{b}	0.030^{b}	1.268^{a}	0.89^{a} (68.48)	0.02^{a} (1.39)	0.30^{a} (23.37)	0.09^{b} (6.79)
D3	$1.820^{a} \pm 0.50$	0.057^{a}	0.137^{a}	1.737^{a}	1.13^{a} (60.21)	0.02^{a} (1.23)	0.50^{a} (26.64)	0.14^{a} (7.46)
D4	$1.297^{a} \pm 0.11$	-	0.067^{b}	1.230^{a}	0.87^{a} (67.09)	0.04^{a} (2.85)	0.31^{a} (23.68)	0.11^{a} (8.25)
D5	$1.350^{a} \pm 0.10$	0.030^{a}	0.100^{a}	1.280^{a}	0.98^{a} (71.01)	0.06^{a} (3.99)	0.24^{a} (17.03)	0.11^{a} (7.97)
D6	$1.467^{a} \pm 0.08$	0.040^{a}	0.047^{b}	1.463^{a}	1.02^{a} (67.90)	0.01^{a} (0.86)	0.28^{a} (18.58)	0.19^{a} (12.41)
D7	$1.330^{a} \pm 0.04$	0.085^{a}	0.075^{b}	1.345^{a}	0.99^{a} (69.61)	0.04^{a} (2.83)	0.29^{a} (20.14)	0.11^{a} (7.42)
Mean	1.496 ± 0.21	0.034	0.079	1.453	1.019 (68.11)	0.03 (2.00)	0.34 (22.72)	0.13 (8.69)
P Value	0.067	0.049	0.038	0.064	0.057	0.260	0.052	0.045

*± Standard deviation (SD); *Cultivated land includes agroforestry systems also; values in parenthesis are the percent of the average land owned (ha HH^{1}); different upper case small letter showed statistical difference in different distance classes using t-test at 0.05 probability level.*

TABLE 5 Livestock number, consumption of fodder and fuelwood per household at different distance classes from reservoir distances

Distance classes	Average livestock number per household						Fodder (kg day^{-1} HH^{-1})	Fuelwood (kg day^{-1} HH^{-1}
	Cow	Bullock	Goat	Sheep	Buffaloes	Total		
D1	1.17^{b} (17.07)	1.50^{a} (21.95)	2.50^{ab} (36.59)	1.00^{a} (14.63)	0.67^{a} (9.76)	$6.83^{ab}\pm0.98$	$42.28^{e}\pm17.94$	$20.46^{ab}\pm4.53$
D2	1.50^{b} (21.43)	1.17^{a} (16.67)	2.67^{ab} (38.10)	0.83^{a} (11.90)	0.83^{a} (11.90)	$7.00^{ab}\pm0.89$	$56.93^{c}\pm18.77$	$21.31^{a}\pm1.87$
D3	1.33^{b} (21.05)	1.33^{a} (21.05)	1.67^{c} (26.32)	1.00^{a} (15.79)	1.00^{a} (15.79)	$6.33^{ab}\pm1.15$	$47.11^{d}\pm27.89$	$19.18^{b}\pm3.31$
D4	2.33^{a} (31.82)	1.00^{ab} (13.64)	3.00^{a} (40.91)	0.33^{b} (4.55)	0.67^{a} (9.09)	$7.33^{a}\pm0.58$	$70.17^{a}\pm3.64$	$19.63^{b}\pm2.53$
D5	2.50^{a} (38.46)	1.00^{ab} (15.38)	2.50^{ab} (38.46)	-	1.00^{a} (15.38)	$6.50^{ab}\pm0.71$	$70.56^{a}\pm11.55$	$19.50^{b}\pm0.08$
D6	2.00^{a} (25.00)	1.00^{ab} (12.50)	3.33^{a} (41.67)	0.67^{a} (8.33)	1.00^{a} (12.50)	$8.00^{a}\pm1.73$	$63.34^{b}\pm12.70$	$16.52^{c}\pm1.83$
D7	1.50^{b} (27.27)	0.50^{c} (9.09)	2.50^{ab} (45.45)	-	1.00^{a} (18.18)	$5.50^{b}\pm0.71$	$51.56^{c}\pm7.54$	$17.17^{bc}\pm1.18$
P Value	0.041	0.036	0.034	0.041	0.190	0.044	0.032	0.046

± Standard deviation (SD), values in parenthesis are the per cent of total number of animals; different upper case small letter showed statistical difference in different distance classes using t-test at 0.05 probability level.

3.7 | Correlation Study

The interrelations among various socioeconomic factors near water reservoirs are intricate, reflecting a web of connections between economic growth, environmental sustainability, social dynamics, and policy influences. To explore these interconnections, we conducted a correlation analysis of 14 key variables, as shown in Table 8. The findings indicate that the total number of households is positively correlated with both the total human population and the number of agricultural laborers per household. Notably, a significant positive correlation exists between the total human population and agricultural labor per household, highlighting how population density can drive labor needs in agriculture. Additionally, the total land owned per household exhibits a strong positive correlation with both cultivated and *ghasni* (grassland) land. This suggests that larger landholdings may facilitate more extensive agricultural activities. There are also significant positive correlations between cultivated land and *ghasni*, as well as between the literacy rate and agricultural labor per household. Moreover, a positive relationship is noted between average livestock population and average fodder consumption, reinforcing the idea that increased agricultural activities generate employment opportunities not only in farming but also in ancillary sectors like processing, transportation, and marketing. However, the analysis revealed some negative correlations as well. The literacy rate is negatively correlated with *ghasni*, while total owned land, cultivated land, and *ghasni* are negatively correlated with average fodder consumption. Interestingly, a negative correlation was also observed between the knowledge of agroforestry and fuelwood consumption. Family size and sex ratio did not show any correlation with the other socioeconomic variables, indicating that these factors may operate independently in this context.

TABLE 7 Farmers keeping knowledge of agroforestry at different distance classes from reservoir

Distance Classes	Household having knowledge of agroforestry (%)
D1	30.67[d]
D2	30.33[d]
D3	33.33[c]
D4	33.33[c]
D5	42.50[a]
D6	40.00[b]
D7	42.50[a]
Mean	36.09
P Value	0.034

*Z-test used to find statistical difference; small case letters denote significant difference at 0.05 probability level.

TABLE 6 Share of different sources of income in total household income at different at different distance classes from reservoir

Distance classes	Share %				
	Income from agriculture	Income from Gov. Job	Income from Fishery	Income from Dairy	Other Sources
D1	56.00[a]	6.30[a]	7.00[a]	19.30[a]	11.30[e]
D2	50.00[c]	4.80[b]	3.70[b]	15.00[c]	26.50[c]
D3	48.30[c]	3.00[c]	2.30[b]	13.30[d]	33.00[b]
D4	48.30[c]	5.70[ab]	0.70[c]	13.30[d]	32.00[b]
D5	52.50[b]	5.50[ab]	3.00[b]	17.50[b]	21.50[d]
D6	53.30[b]	4.70[b]	1.70[c]	18.30[b]	22.00[d]
D7	42.50[d]	4.00[b]	0.50[c]	7.50[e]	45.50[a]
P Value	0.021	0.047	0.030	0.026	0.019

**Z-test used to find statistical difference; upper case small letters denote significant difference at 0.05 probability level.*

The correlation analyses revealed that while economic development associated with reservoir proximity spurs growth, it may inadvertently widen income disparities if gains are not equitably distributed. This mirrors findings by Konwar (2015) and underscores the importance of inclusive development. Agroforestry has shown promise as a balancing mechanism by uplifting marginalized groups through enhanced income, gender empowerment, and ecological stability (Mukhlis *et al.,* 2022). Shi *et al.* (2019) reinforced the notion that dams and large infrastructure must be accompanied by equitable resource-sharing policies to avoid social fragmentation.

4 | CONCLUSIONS

A detailed assessment of the socio-economic landscape around the 'Gobind Sagar Reservoir' revealed that households located in close proximity to the reservoir generally hold larger land parcels, likely benefiting from better access to water resources for irrigation and associated agricultural advantages. In contrast, households farther from the reservoir tend to demonstrate greater familiarity with agroforestry practices and utilize more fodder, reflecting adaptive strategies to optimize limited resources. Agriculture remains the principal livelihood for these communities, supplemented by income from small businesses, dairy farming, government employment, and fisheries-activities often bolstered by the reservoir's influence on water availability and economic opportunities. Farmers actively cultivate woody perennials and bamboo species, establishing diversified agroforestry systems that not only enhance economic returns but also promote environmental sustainability. These patterns illustrate how the reservoir shapes both land use and resource management decisions, highlighting the adaptive measures households employ to navigate socio-economic and ecological challenges in the region.

TABLE 8 Pearson correlation matrix between different socioeconomic variables of farm families at different distance classes from reservoir

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	0.99**													
3	-0.02	0.01												
4	-0.10	-012	-0.16											
5	0.13	0.12	-0.20	-0.12										
6	-0.04	-0.01	0.16	-0.27	-0.35									
7	-0.05	-0.03	0.15	-0.26	-0.24	0.97**								
8	-0.06	-0.03	0.19	-0.30	-0.51**	0.89**	0.79**							
9	0.08	0.06	-0.23	-0.03	0.33	-0.25	-0.26	-0.33						
10	-010	-0.10	0.06	-0.01	-0.20	0.29	0.29	0.33	-0.18					
11	0.23	0.23	-0.08	0.23	0.03	-0.15	-0.09	-0.18	-0.30	-0.11				
12	0.67**	0.68**	0.00	-0.24	0.42*	0.10	0.12	-0.07	0.08	-0.28	0.11			
13	0.32	0.30	-0.03	0.21	0.29	-0.76**	-0.72**	-0.81**	0.52**	-0.36	0.16	0.15		
14	0.00	0.00	-0.08	-0.07	0.13	0.03	0.03	0.03	-0.06	0.28	-0.43*	0.05	-0.22	1.00

***. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.*

Where, 1-Total number of households, 2-Total human population, 3-Family size, 4-Sex ratio, 5-Literacy rate, 6-Total land owned, 7-Cultivated land, 8-*Ghasni* (grassland), 9-Av. Livestock population, 10-Income from agriculture, 11-Knowledge of agroforestry, 12-Agriculture labour HH^{-1}, 13-Av. fodder consumption and 14-Av. fuelwood consumption.

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CONFLICT OF INTEREST

The authors state that they have no financial or personal connections that could have influenced the work in this paper.

DATA AVAILABILITY STATEMENT

Data will be provided upon request.

AUTHOR'S CONTRIBUTION

SS: Investigation, resources, formal analysis, visualization, writing - original draft; BG & DRB: Supervision, conceptualization, writing - review and editing; PP, DK ,CL and PS: Review and editing.

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