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Assessment of Water Storage to Socio-environment Impacts and Inundation Mapping under Dam Height Variations in Sunkoshi III Hydropower Project, Nepal

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Abstract

Hydropower development in the mountainous regions of Nepal requires thorough assessments of both technical feasibility and socio-environmental impacts. This study looks at how different dam heights affect water storage for the proposed Sunkoshi III Hydropower Project. It focuses on inundation mapping and the socio-environmental consequences that follow. By using GIS-based spatial analysis along with demographic data from ten municipalities that will be affected, we modeled how much area would be inundated at water levels between 664 meters and 734 meters. The findings show that as water levels rise, there is a quick increase in the area submerged, the volume of water, the number of displaced households, flooded farmland, and damage to roads. At the highest water level in 734 m, over 37 million square meters of land would be underwater, around 3,825 households and 3.7 million square meters of farmland are impacted. The population at risk includes residents from more than ten municipalities, with the greatest exposure observed in Chautara, Sangachok Gadhi and Indrawati areas.

Keywords: *ArcGIS, Inundation mapping, Socio-environment Impact, Sunkoshi Hydropower Project-III*

1. Introduction

Nepal has a wealth of water resources by its river systems and mountainous landscape present remarkable opportunities for the development of hydropower (Bhatt & Joshi, 2024). In mountainous areas like Nepal, hydropower development presents enormous potential for sustainable energy production, but it also presents significant obstacles because of the regional complicated topography, monsoonal climate, seismic activity, and water-induced hazards like landslides, floods, and sedimentation (Pandey & Patodiya, 2023). One notable example of a significant energy infrastructure project is the Sunkoshi III Hydropower Project. Construction of dams invariably results in the submersion of upstream land due to the artificial storage of water, which affects not only the natural ecosystem but also agricultural land, human settlements, and infrastructure like public utilities and roads. The height of the dam has a direct impact on the spatial extent of water impoundment, which in turn determines the magnitude of these impacts. The area and volume of inundation increase with dam height, which has more significant effects on land use change, relocation, and displacement (Bhattarai et al., 2024). Therefore, for well-informed project planning, risk mitigation, and sustainable development, it is essential to comprehend the spatial dynamics of inundation across different dam heights.

The proposed Sunkoshi Hydropower Project-III is a large scale, storage type hydroelectric project planned on the Sunkoshi River, spanning four districts i.e. Kavrepalanchok, Ramechhap, Sindhuli, and Sindhupalchowk, over an area of approximately 5,520 km^2 (IBN, 2019). Located about 60 km east of Kathmandu (coordinates: 27.7537°N, 85.8380°E), the project involves constructing a 160 meter wide and 180 meter high dam between Temal Rural Municipality of Kavrepalanchok and Lubhughat in Ramechhap District (NewSpotlight, 2022). The Sunkoshi-III project has been included in long-term national planning initiatives. Earlier feasibility studies such as the Koshi River Master Plan (JICA, 1985) and the Nationwide Master Plan Study on Storage Type Hydropower Development (JICA, 2014) recommended its development with a capacity of 536 MW. However, the current design proposes an upgraded capacity of 683 MW (Bhatta, 2022), aiming to utilize 570 m^3/s of water through a pair of penstocks to generate electricity at a powerhouse located approximately 400 meters downstream of the dam site (NewSpotlight, 2022).

Water induced hazards pose a serious threat to the Sunkoshi Hydropower Project-III project area. These include upstream landslides, riverbank erosion, monsoon driven flash floods, and sediment inflows that endanger downstream communities, infrastructure integrity, and dam safety (Shrestha & Nakagawa, 2016; Talchabhadel et al., 2023). Over 5,000 households could be fully or partially impacted by the project construction, which will create a 45 kilometer reservoir with an estimated gross storage of 1,220 million m^3 (NewSpotlight, 2022). Particularly during extreme hydro meteorological events, the inundation of settlements, the disruption of local infrastructure, and the increased sedimentation pressure on the reservoir may result in compounded hazards. Hazard risk mapping is crucial for efficient project planning, disaster preparedness, and environmental safety in the Sunkoshi-III project location and geophysical context. Identification and mapping of potential water induced hazards, risks of inundation, and water depth by reservoir height of the project will be supported to protect infrastructure, and a scientific foundation for mitigation strategies. This paper attempts to assess and map these water induced hazards risks using Geographic Information Systems (GIS) in order to model the spatial extent of hazards and their effects across different elevation levels. This will support integrated water risk management in the Sunkoshi-III hydropower development corridor. In order to meet this need, this study performs a GIS-based inundation analysis at 10 meter intervals across water levels ranging from 664 m to 734 m. The study simulates and assesses the effects of different reservoir levels by superimposing hydrological, topographical, and socioeconomic datasets using ArcGIS 10.4 tools, such as the Spatial Analyst and 3D Analyst extensions. Land use data, population statistics, district and provincial boundary shape files, and SRTM 30 m resolution DEM are important datasets.

2. Data and Method

2.1 Study Area

The Sunkoshi Hydropower Project-III is situated in the Kavrepalanchok District, the central part of Nepal, which is part of Bagmati Province. The proposed dam site is at coordinates 27°31'25.63" N and 85°47'21.14"

E, nestled in the mid-hill physiographic region. This location acts as a central point for various spatial analyses, like watershed delineation and inundation modeling, which are carried out using ArcGIS software, specifically ArcMap 10.4 and its extensions. The project is planned along the Sunkoshi River, a significant river system in Nepal. This river starts in the high Himalayas and travels south through steep mountains before it eventually joins the Koshi River system. The Sunkoshi River basin stretches from around 595 meters all the way up to 7,945 meters above sea level. It covers everything from the mid-hills to the high mountains, even reaching into parts of China. The whole catchment area is about 5,520 km^2, and roughly 40% of that sits in Tibet, China. On the administrative side, the Sunkoshi Hydropower Project-III sits in both Kavrepalanchok and Sindhupalchok Districts, involving a lot of local governments. According to the feasibility study conducted by Nepal Electricity Authority (NEA), the study sets 2027 as the starting year for construction, with the goal of having the project up and running by 2031.

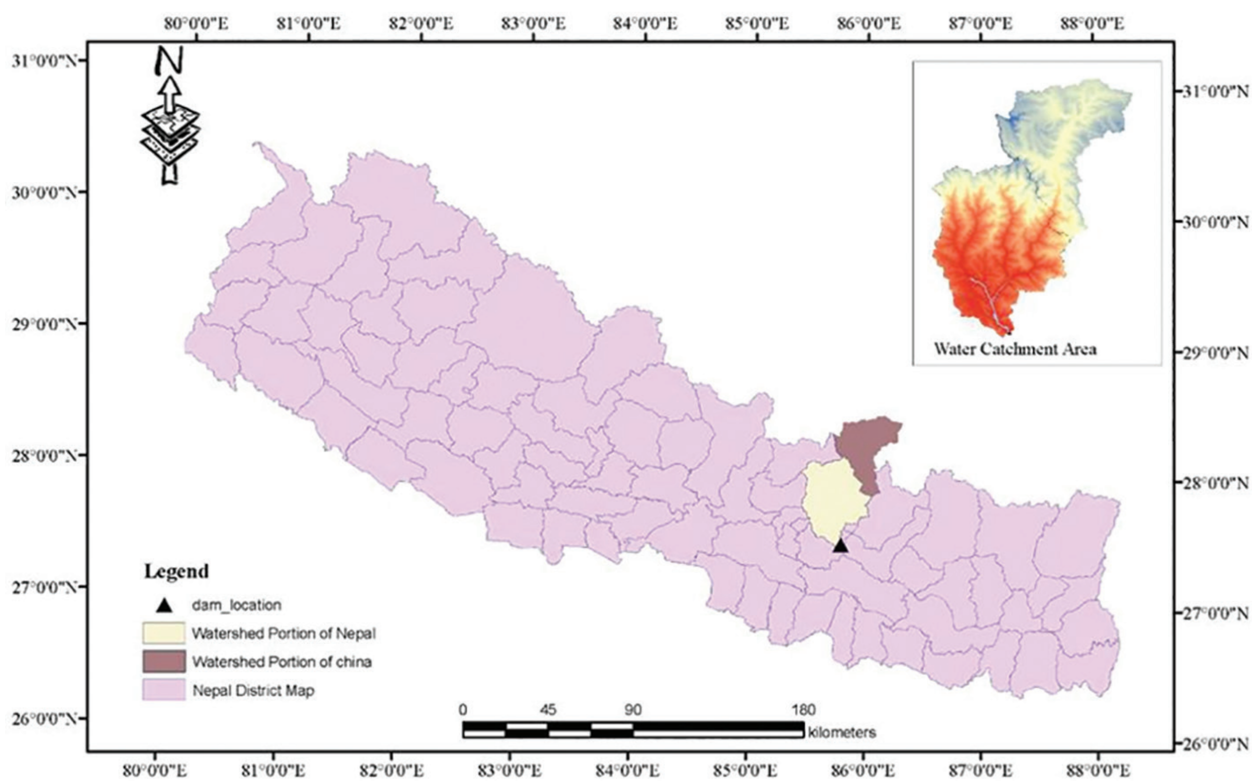

Figure 1: Study area

The Sunkoshi River brings a lot of complexity to this project. Its flow swings wildly throughout the year from as low as 193.7 to 1,990 m^3/s. That is mostly because of the heavy monsoon rains, which dump about 80% of the regional annual rainfall between June and September (Yadav & Prajapati, 2025). On average, the basin sees anywhere from 1,500 to 3,000 mm of rain each year, so you get constant fluctuations in the river. Floods and landslides are a real concern during monsoon season (Prajapati et al., 2025). The dam itself will stand 180 meters tall, with a crest that stretches 160 meters across. It is set to hold a total of 1,220 million m^3 of water, with 550 million m^3 reserved for power generation. The engineering team designed the system to work with a net head of 109.3 meters, so it keeps running efficiently even when the river flow changes.

2.2 Data Collection and Method

This study used ArcGIS 10.4 geospatial analysis techniques to assess the extent of reservoir inundation and its effects on infrastructure, population, and land related to the proposed Sunkoshi III Hydropower Project. Data collection, preprocessing, watershed delineation, inundation modeling, and impact analysis were all included in the methodology. Figure 2 depicts the overall process flow.

The Digital Elevation Model (DEM), dam location, land use map, administrative boundaries, transportation infrastructure, population data, and water depth levels were among the first datasets needed. The DEM, which had a 30-meter spatial resolution, was obtained from Open Topography. This was essential to the creation of inundation surfaces and terrain analysis. While the reservoir spread reaches into portions of Sindhupalchok District, the dam location was designated as 27°31'25.63"N and 85°47'21.14"E in the Kavrepalanchok District. In order to capture more scenarios, the reservoir elevation levels were examined between 664 and 734 meters above mean sea level, which is higher than the JICA-recommended operational range of 674 to 700 meters.

Provinces, districts, municipalities, and wards administrative shape files were gathered from reliable sources. These were employed to evaluate which particular administrative units were impacted. Land categories like agricultural, forested, and built-up areas were also distinguished using land use maps. Overlay and impact calculations also made use of transportation infrastructure shape files (such as local and national roads) and population raster data. Projecting all spatial datasets to Zone 45N of the Universal Transverse Mercator (UTM) coordinate system using the WGS 1984 datum was the first step in the preprocessing process. The Fill tool was used for DEM conditioning in order to eliminate sinks and guarantee hydrologic continuity. The catchment area pertinent to the dam site was clipped from the DEM. The study made extensive use of ArcGIS Spatial Analyst and 3D Analyst extensions. The filled DEM flow direction and flow accumulation raster were used in the watershed delineation process. In order to precisely replicate the natural drainage pattern, a pour point was manually set at the dam location. For all further analysis, a clipped DEM known as the watershed DEM was extracted from the watershed raster produced by this step. Impact zones and overall catchment coverage were subsequently calculated using this watershed area.

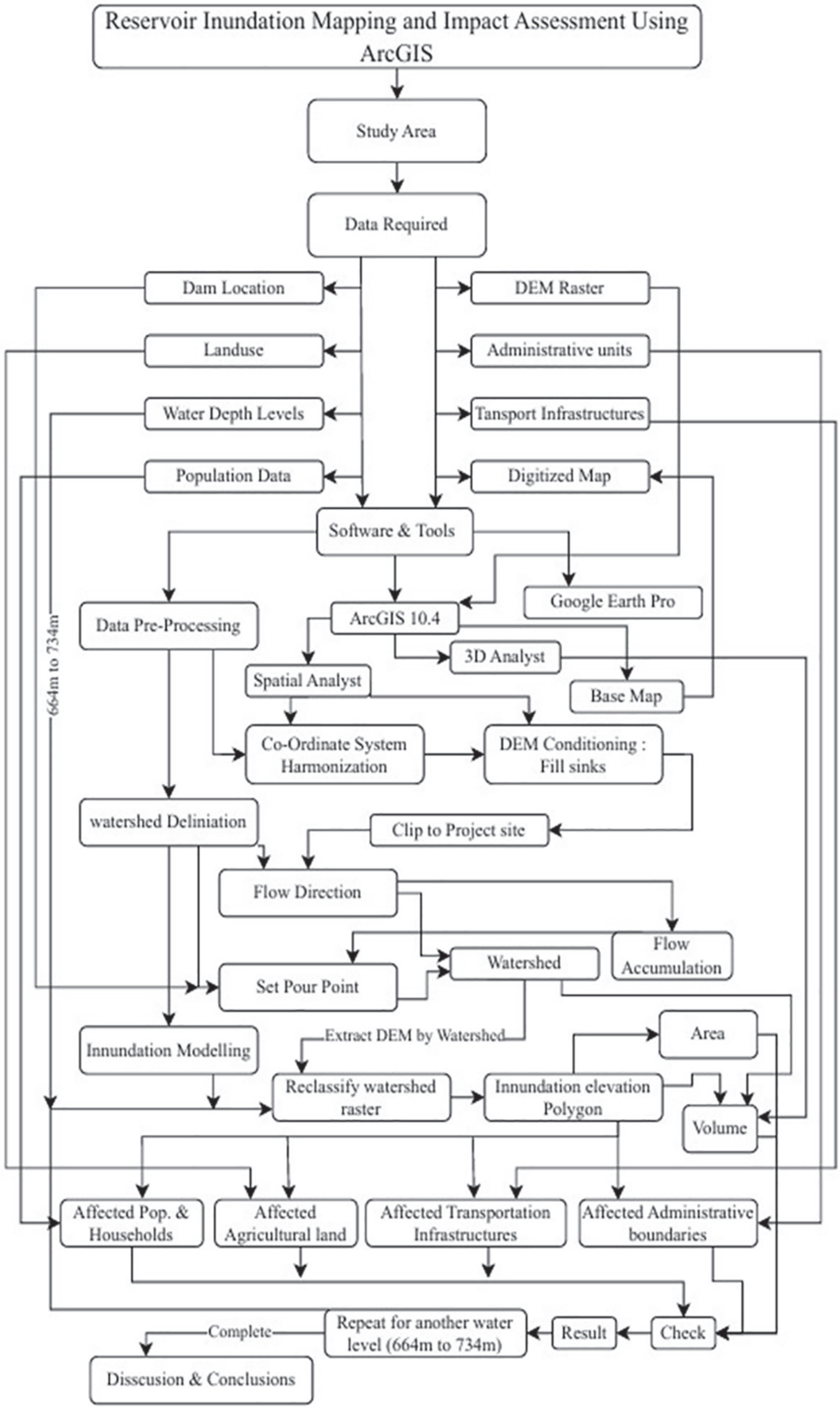

Figure 2: Research flow chart

Several elevation levels were simulated for inundation modeling as 664 m, 674 m, 684 m, 694 m, 700 m, 714 m, and 734 m. The watershed DEM was reclassified at each elevation in order to separate pixels that were below the desired water level. After that, these raster cells were transformed into polygon features that symbolized flood zones. The Surface Volume tool in the 3D Analyst extension was used to calculate the surface areas and volumes of each inundation polygon, with the reference plane set below the corresponding elevation level. In terms of square kilometers (m^2) and million cubic meters (m^3), respectively. Each inundation polygon was intersected with the corresponding spatial datasets in order to assess the impact. In order to calculate the number of impacted people and households, the raster layer was clipped by inundation zones for population analysis. To calculate the loss of cultivated areas in m^2, land use layers were clipped similarly in agricultural impact analysis. By clipping the transportation shape file with each inundation polygon, dissolving the clipped output, and adding up the total affected road length, the impact on road infrastructure was assessed. In order to help with future compensation and policy decisions, affected administrative boundaries districts, municipalities, and wards were also intersected with inundation zones to determine which governance units would be impacted.

This methodology was applied iteratively for all the defined levels of elevation. Validation of the outputs was carried out through overlay methods and manual checks using Google Earth Pro software. Microsoft Excel was used for tabulating the results, summarizing the results, and performing comparative analyses for the outputs using the elevation intervals. This methodology enabled the quantification of the impacts of inundation with spatial accuracy, providing evidence based recommendations for planning, mitigation, and resettlement for the Sunkoshi III Hydropower Project.

3. Results and Discussions

3.1 Inundation Mapping

The inundation mapping was carried out using GIS-based spatial analysis techniques for varying proposed height ranges of the dam from 684 m to 724 m. The results clearly indicate that there is an expansion of inundated areas with an increase in the height of the proposed dam. In the case of the proposed height of 684 m, the inundated areas include low lying agricultural lands, rural settlements, and forest areas in places like Temal, Chaurideurali, Panchkhal, and so on. As the height of the proposed dam is raised to 700 m, there is an increase in the inundated areas that include farmlands, access roads, settlements in places like Mandandeupur, Chautara Sangachok Gadhi, Indrawati, and so on. As the height of the proposed dam is raised to 714 m, there is an increase in inundated areas that include farmland settlements, public infrastructure like schools, health centers, quarry areas in places like Mandandeupur, Chautara Sangachok Gadhi, Indrawati, and so on. As the height of the proposed dam is raised to 724 m, inundated areas include places like Melamchi Municipality suburban zones, forest areas, farmlands, and recreational areas (Figure 3).

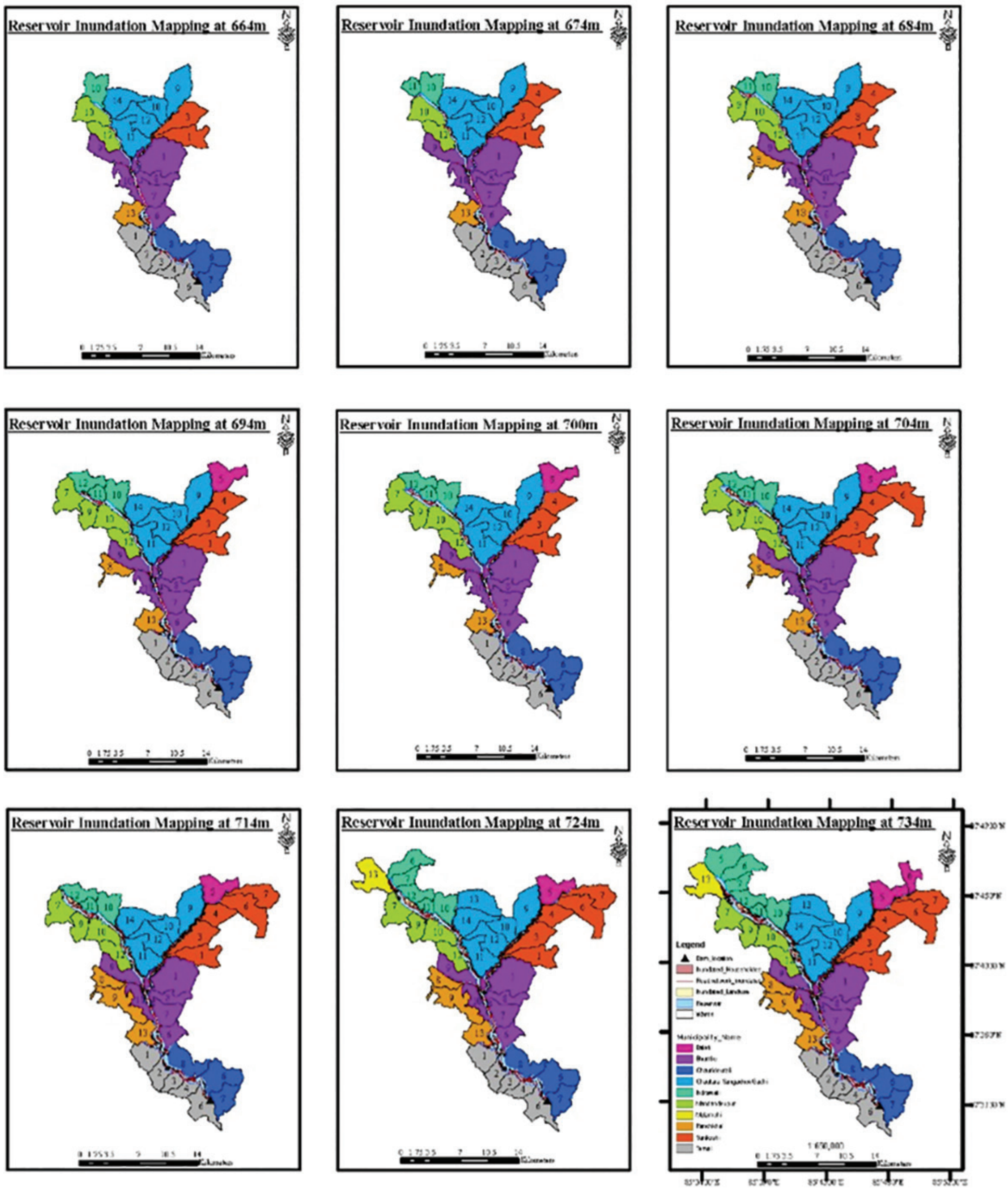

Figure 3: Innundation impact maping for different water level

This is supported by quantitative data showing that the area of land inundated rises from 13.3 million m² to over 37.1 million m² as the elevation rises from 664 meters to 734 meters. In the same vein, as presented in Table 1, the volume of water stored rises from 407 million m³ to over 2,082 million m³, showing a disproportionate increase in volume relative to area as a result of terrain flattening with elevation increase. In all cases, farmland and forests dominate the areas of inundated land use, whereas residential areas experience an increase in the extent of inundation, particularly after the 700 m mark. This analysis of the spatial dimensions of the issue underscores the need for appropriate and effective land use planning strategies in line with dam elevation scenarios.

Table 1: Inundated Area, Inundation Volume, Household Affected, Farmland Affected and Road Length Affected at Different Water Levels.

Water Level (m)	Inundated Area (m^2)	Inundation Volume (m^3)	Households Affected	Farmland Affected (m^2)	Road Length Affected (m)
664	13,313,506.46	407,284,997.79	1,006	604,280.07	58,306.46
674	13,884,674.97	537,814,789.86	1,235	776,920.82	70,394.82
684	18,564,745.39	723,064,293.49	1,451	948,031.39	86,053.62
694	21,687,136.72	922,905,036.03	1,753	1,352,875.92	101,046.57
700	23,777,496.28	1,059,214,540.55	1,865	1,856,050.74	109,551.83
704	25,267,104.69	1,157,002,115.70	1,973	2,176,819.35	115,686.53
714	28,658,478.02	1,425,743,460.28	2,264	2,546,021.86	129,980.64
724	32,941,978.39	1,733,630,593.97	2,906	3,171,435.69	152,415.54
734	37,094,408.95	2,082,853,995.72	3,825	3,707,468.09	174,395.76

3.2 Environmental Impacts of Reservoir Expansion

Table 1 shows the overall examination of the effects of differing water levels on the area of inundation, volume, and socio-economic factors in the Sunkoshi III Hydropower Project region. The area inundated, volume of inundation, number of households affected, farmland and the length of roads are significantly higher when the water level increases beyond 664 meters to 734 meters. The flood at 664 meters of water level covers some 13.3 million m² of land, which displaces 1, 006 households and 604, 280 m² of fertile land. The higher the water level, the higher the area and volume inundated which touches 1,235 households and 776,920 m² of agricultural areas. An even greater effect is experienced at 684 m with almost 18.6 million m² being flooded and 1,451 households being affected. The process goes on and the water level will reach 700 meters causing the flooded area to reach 23.8 million m², and 1,865 households affected and more than 1.8 million m² of agricultural land under water. The alternative situation that illustrates the highest water level of 734 m flooding above 37 million m² has to do with 3,825 households, almost 3.7 million m² of agricultural land, and 174,395.76 m of roads. These values indicate a geometric growth of socio-economic and infrastructural effects with each incremental change in reservoir level implying the dire necessity to plan and evaluate the risks associated with reservoir level carefully.

Table 2 enumerates the municipalities and wards that have been affected, with the population, and there is the human cost of inundation in the area of Sunkoshi III project. Chautara, Sangachok Gadhi is one of the most densely populated municipalities, and the potential population that has been affected is the largest in Sangachok Gadhi which has 17,631 individuals in six wards. In a similar manner, the number of people in the affected wards in Indrawati Municipality stands at 13277, Sunkoshi with 11423 and Bhumlu with 10579 people. Mandandeupur too has a high number of people at risk with 10,030, Chaurideurali, Temal, and Panchkhal where the population is 6,624, 8,406, and 5,438 respectively. Despite having only two wards, Balefi has 4,866 individuals in the risky area. Melamchi is the area with the least population at risk with 3,609 people in ward 13. This demographic breakdown is useful in identifying the most vulnerable communities which will need either resettlement, compensation, or protection to address the inundation risk. The combination of data between the two tables emphasizes the magnitude and intensity of the management cost of the socio-environmental effects of the dam-induced inundation in the Sunkoshi III Hydropower Project.

Table 2: No. of Affected Population of Different Wards from Various Municipality at 734m Water Level.

S.N.	Municipality	Ward	Population
1	Balefi	5	2555
		6	2311
		Total	4866
		1	2560
		6	1195
		7	1146
2	Bhumlu	8	1941
		9	1924
		10	1813
		Total	10579
		6	2306
		7	1477
3	Chaurideurali	8	1784
		9	1057
		Total	6624
		9	3709
		10	3110
		11	3489
4	Chautara SangachokGadhi	12	2139
		13	3147
		14	2037
		Total	17631
		5	2622
		6	1602
		7	1506
5	Indrawati	10	2449
		11	1840
		12	3258
		Total	13277

S.N.	Municipality	Ward	Population
6	Mandandeupur	7	3073
		9	2352
		10	2702
		12	1903
		Total	10030
7	Melamchi	13	3609
8	Panchkhal	8	1913
		9	2196
		13	1329
		Total	5438
9	Sunkoshi	1	2054
		3	2035
		4	1246
		6	3026
		7	3062
		Total	11423
10	Temal	1	2035
		2	1869
		3	914
		4	1684
		6	1904
		Total	8406

The inundation analysis using different water level under 664 to 734 m of water level as seen in Table 3, indicates that the area of affected land, the type of land use, the municipalities and wards, and the road infrastructure has been gradually increasing. The land area of 1.67 million m^2 is touched by the lowest level of water, and it is mainly farmland (36.27%), forest (34.48%), and residential lands (22.42%). The most affected municipalities at this stage are Bhumlu, Chaurideurali, Chautara Sangachok Gadhi, Indrawati, Mandandeupur, Panchkhal, Sunkoshi and Temal. The total number of kilometers of roads that are flooded is 58.3 km and the highest number of kilometers is the path and tertiary roads. The floods cover a size of more than 2.3 million m^2 as the water reaches a level of 674 m. The length of the affected road network is raised to approximately 70.4 km, and secondary and trunk roads get submerged.

The area that is affected becomes enormous to an area of more than 3 million m^2 at a water level of 684 m. The most affected land cover is forest (43.58%), and farmland and residential space (31.47% and 18.53%) respectively. The affected road length increases to approximately 86 km with the most affected being the paths and tertiary roads. More than 4 million m^2 of land is flooded at 694 m of water level. Forests occupy the largest percentage of 44.91, and farmlands have 33.68 percent, and the residential areas have 15.55 percent. The concerned municipalities and wards are also on the rise, particularly, in places like Mandandeupur, Chautara, and Sangachok Gadhi. The affected road infrastructure increases to more than 101 kilometers, as trunk and unclassified roads increase by a lot.

The water level increases to 700 m, which is why the flooded territory will be 4.9 million m². The largest percentage (43.82%) remains in the forest areas, then there is farm land (37.88%). The residential areas are dwindled to 13.24%, meaning that floods are extending further to forest and agricultural areas. The total length of road infrastructure submerged is approximately 110 kilometers with improvement in all types of roads including service and footway networks. The area of inundation reaches 5.48 million m² at 704 meters. Forest (43.23%), and farmland (39.73%) are the most hit. The residential territory reduces marginally to 12.18%, and the industrial territory is the first in the data, which suggests the increase of the flood influence into the economic zones. The affected total road length is approximately 115.7 km which include some long distances of path roads, tertiary and trunk roads.

Once the water level hits the mark of 714 m, the area that becomes affected increases even more to 6.57 million m². Forest is still the biggest (45.63%) with farmland and residential areas at 38.77% and 10.92% respectively. There is also a beginning of additional impact on new types of land use like quarry and park, which means that the landscape is even more vulnerable. The length of the inundated roads rise to almost 130 km, which has a massive impact on tertiary, path, and trunk roads. The flooded area is more than 8.19 million m² at 724 meters. Forest (46.05%), farmland (38.70%) and residential areas (9.53%) are the coverages respectively. The land use that is meadow and park shows that there is more expansion to the natural and recreational land. Affected roads escalate to 152 km and all categories of roads, particularly the track and unclassified type roads are considerably flooded.

Table 3: Affected Household and Farmlands due to Inundation

S. N.	Water level	land use results			Municipalities &Wards Affected by Inundation		Roads	
		Types	**Area (sq.m)**	**%of landuse**	**Municipality/ RM**	**Wards**	**Types**	**length(m)**
		farmland	604280.0684	36.27%	Bhumlu	1,6,7,8,9,10	footway	1573.650
		forest	574521.7469	34.48%	Chaurideurali	6,7,8	path	17503.893
		heath	2184.294532	0.13%	Chautara Sangachok Gadhi	9,10,11,12,14	residential	461.012
		residential	373501.0594	22.42%	Indrawati	10	secondary	1550.780
		scrub	111709.0705	6.70%	Mandandeupur	10,12	service	384.867
1	664	Total	1666196.24	100.00%	Panchkhal	13	tertiary	11311.113
					Sunkoshi	1,3	track	5321.433
					Temal	1,2,3,4,6	trunk	6284.635
							unclassified	12787.079
							unknown	1127.992
							Total	58306.455
2	674	farmland	776920.8148	33.37%	Bhumlu	1,6,7,8,9,10	footway	1950.776
		forest	921688.3018	39.59%	Chaurideurali	6,7,8	path	19564.181
		heath	3073.756982	0.13%	Chautara Sangachok Gadhi	9,10,11,12,14	residential	461.012
		residential	475551.095	20.43%	Indrawati	10,11	secondary	2736.367
		scrub	150749.1406	6.48%	Mandandeupur	9,10,12	service	407.874
		Total	2327983.109	100.00%	Panchkhal	8,13	tertiary	12569.399

S. N.	Water level	land use results			Municipalities & Wards Affected by Inundation		Roads	
		Types	**Area (sq.m)**	**%of landuse**	**Municipality/ RM**	**Wards**	**Types**	**length(m)**
					Sunkoshi	1,3,4	track	7327.387
					Temal	1,2,3,4,6	trunk	10070.085
							unclassified	14100.881
							unknown	1206.861
							Total	70394.824
3	684	farmland	948031.3939	31.47%	Bhumlu	1,6,7,8,9,10	footway	2526.383
		forest	1312977.151	43.58%	Chaurideurali	6,7,8	path	22409.923
		heath	5430.865098	0.18%	Chautara SangachokGadhi	9,10,11,12,14	residential	461.012
		residential	558426.2976	18.53%	Indrawati	10,11	secondary	3889.071
		scrub	188104.9437	6.24%	Mandandeupur	9,10,12	service	495.688
		Total	3012970.651	100.00%	Panchkhal	8,13	tertiary	13969.304
					Sunkoshi	1,3,4	track	13256.691
					Temal	1,2,3,4,6	trunk	12347.769
							unclassified	15490.674
							unknown	1207.104
							Total	86053.619
4	694	farmland	1352875.923	33.68%	Balefi	5	footway	3239.991
		forest	1803660.921	44.91%	Bhumlu	1,6,7,8,9,10	path	25228.331
		heath	8702.071235	0.22%	Chaurideurali	6,7,8	residential	734.274
		residential	624394.8801	15.55%	Chautara SangachokGadhi	9,10,11,12,14	secondary	5086.020
		scrub	226913.9363	5.65%	Indrawati	10,11,12	service	560.095
		Total	4016547.731	100.00%	Mandandeupur	7,9,10,12	tertiary	14976.454
					Panchkhal	8,9,13	track	17081.496
					Sunkoshi	1,3,4	trunk	15745.128
					Temal	1,2,3,4,6	unclassified	17187.675
							unknown	1207.104
							Total	101046.568
5	700	farmland	1856050.739	37.88%	Balefi	5	footway	3544.794
		forest	2147175.008	43.82%	Bhumlu	1,6,7,8,9,10	path	26886.720
		heath	9696.6048	0.20%	Chaurideurali	6,7,8	residential	766.432
		residential	648658.009	13.24%	Chautara SangachokGadhi	9,10,11,12,14	secondary	5941.660
		scrub	238864.8415	4.87%	Indrawati	10,11,12	service	780.332
		Total	4900445.203	100.00%	Mandandeupur	7,9,10,12	tertiary	15651.307
					Panchkhal	8,9,13	track	19556.361
					Sunkoshi	1,3,4	trunk	16783.352

S. N.	Water level	land use results			Municipalities & Wards Affected by Inundation		Roads	
		Types	Area (sq.m)	%of landuse	Municipality/ RM	Wards	Types	length(m)
					Temal	1,2,3,4,6	unclassified	18433.768
							unknown	1207.104
							Total	109551.829
		farmland	2176819.354	39.73%	Balefi	5	footway	3774.949
		forest	2368811.29	43.23%	Bhumlu	1,6,7,8,9,10	path	28638.380
		heath	13353.53	0.24%	Chaurideurali	6,7,8	residential	766.432
		industrial	3094.255468	0.06%	Chautara SangachokGadhi	9,10,11,12,14	secondary	6496.401
		residential	667559.5853	12.18%	Indrawati	10,11,12	service	766.650
6	704	scrub	249379.2777	4.55%	Mandandeupur	7,9,10,12	tertiary	16119.645
		Total	5479017.292	100.00%	Panchkhal	8,9,13	track	21074.498
					Sunkoshi	1,3,4,6	trunk	17314.405
					Temal	1,2,3,4,6	unclassified	19528.066
							unknown	1207.104
							Total	115686.530
		farmland	2546021.856	38.77%	Balefi	5	footway	4155.489
		forest	2996407.713	45.63%	Bhumlu	1,6,7,8,9,10	path	32202.739
		heath	14836.897	0.23%	Chaurideurali	6,7,8	residential	766.432
		industrial	5563.170	0.08%	Chautara SangachokGadhi	9,10,11,12,14	secondary	8007.622
7	714	quarry	24525.362	0.37%	Indrawati	10,11,12	service	863.230
		residential	717102.814	10.92%	Mandandeupur	7,9,10,12	tertiary	17622.368
		scrub	262544.114	4.00%	Panchkhal	8,9,13	track	24106.849
		Total	6567001.927	100.00%	Sunkoshi	1,3,4,6,7	trunk	18724.070
					Temal	1,2,3,4,6	unclassified	22324.741
							unknown	1207.104
							Total	129980.644
8	724	farmland	3171435.685	38.70%	Balefi	5	footway	4893.888
		forest	3773571.936	46.05%	Bhumlu	1,6,7,8,9,10	path	38545.075
		heath	19550.267	0.24%	Chaurideurali	6,7,8	residential	994.754
		industrial	5563.172	0.07%	Chautara SangachokGadhi	9,10,11,12,13,14	secondary	9813.870
		meadow	104068.596	1.27%	Indrawati	6,7,10,11,12	service	863.230
		park	219.902	0.00%	Mandandeupur	7,9,10,12	tertiary	18829.176
		quarry	30181.946	0.37%	Melamchi	13	track	31086.718
		residential	780771.228	9.53%	Panchkhal	8,9,13	trunk	21075.440
		scrub	308720.475	3.77%	Sunkoshi	1,3,4,6,7	unclassified	25106.283
		Total	8194083.206	100.00%	Temal	1,2,3,4,6	unknown	1207.104

S. N.	Water level	land use results			Municipalities & Wards Affected by Inundation		Roads	
		Types	**Area (sq.m)**	**%of landuse**	**Municipality/ RM**	**Wards**	**Types**	**length(m)**
							Total	152415.536
		farmland	3707468.090	38.27%	Balefi	5,6	footway	5702.598
		forest	4529717.317	46.76%	Bhumlu	1,6,7,8,9,10	path	45234.596
		heath	19564.168	0.20%	Chaurideurali	6,7,8,9	primary	31.322
		industrial	5563.172	0.06%	Chautara Sangachok Gadhi	9,10,11,12,13,14	residential	1051.093
		meadow	111641.160	1.15%	Indrawati	5,6,7,10,11,12	secondary	13857.753
		park	2765.705	0.03%	Mandandeupur	7,9,10,12	service	863.230
9	734	quarry	30181.946	0.31%	Melamchi	13	tertiary	20152.893
		residential	926358.584	9.56%	Panchkhal	8,9,13	track	34546.034
		scrub	354201.648	3.66%	Sunkoshi	1,3,4,6,7	track-grade4	13.176
		Total	9687461.789	100.00%	Temal	1,2,3,4,6	trunk	23252.743
							unclassified	28483.215
							unknown	1207.104
							Total	174395.758

Lastly, when the water level is at its highest recorded level of 734 m, the most area is affected by the inundation of 9.69 million m^2. Forest still reigns (46.76%), then there are farmlands (38.27%) and residential (9.56%). There is a growing dominance of meadow, quarry and industrial landforms that are indicative of a widespread effects of floods in agricultural, residential, and industrial areas. The affected road network peaks at 174.4 km and the path, tertiary, and trunk type of roads were severely damaged which is also shown on Figure 4. In general, the statistics demonstrate the evident tendency of growing the severity of inundation with a rise in the water level, a more extensive scope of impacted land use categories, cities, and roads. The most common land uses that are affected include forest and farm land whereas tertiary, path and trunk roads are the ones that suffer most due to the transportation disturbances. The slow integration of industrial, quarry and parklands underscores the increasing socio-economic significance of increased heights of floods in the area.

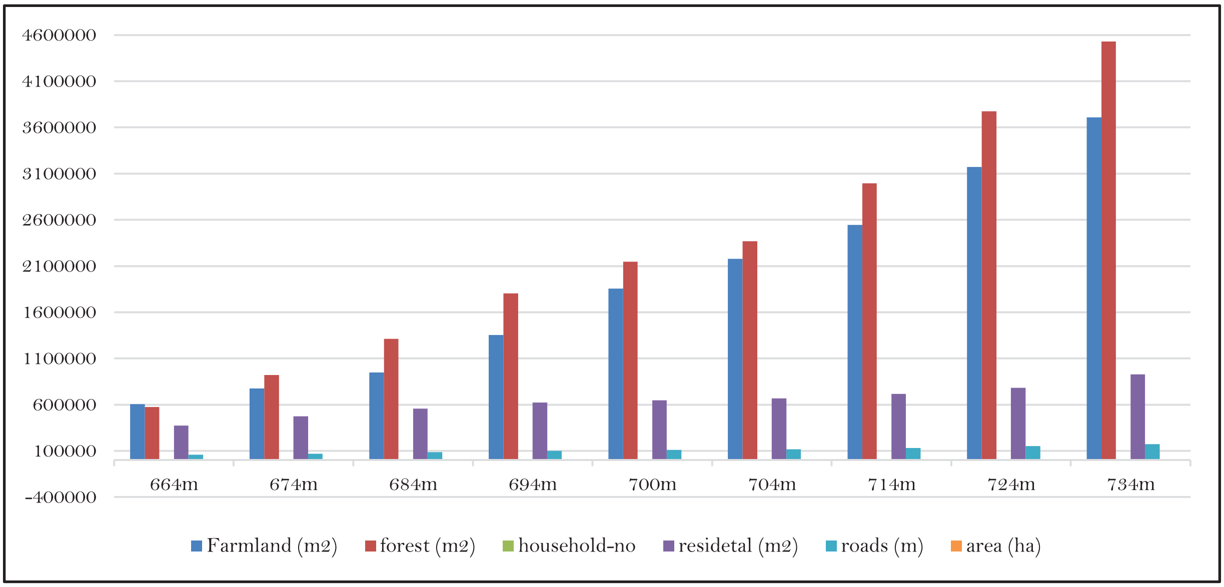

Figure 4: Socio-spatial impact variation on change on dam height

4. Conclusion

In the research, the authors provide an in-depth discussion of water storage and their socio-environmental consequences with the height variations of the dams in the Sunkoshi III Hydropower Project. Based on the inundation mapping and demographic examination using GIS, we can clearly imagine that as the water level increases in small steps, the human settlements, agricultural lands and even the infrastructure are affected in disproportionately large portions. As an example, the increase in the level of reservoir, which is 664 m to 734 m, makes the inundated plasma 13.31 m^2 to more than 37 million m^2, and the inundated household to be 1,006 to 3,825. Moreover, the agricultural land and road network is almost fourfold in this range. The demographic statistics also highlight the scale of displacement risk especially in such municipalities as Chautara, Sangachok Gadhi, Indrawati, and Sunkoshi. These results reveal the necessity of integrating the planning process that does not only focus on the hydropower generation, but also on the socio-economic tradeoffs associated with the height choice of the dams. The methodology and findings can form a basis of future environmental impact evaluation, compensation models and sustainable infrastructure development on the river basins in Nepal.

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