Spatio-Temporal Analysis of Hydropower Projects with Terrestrial Environmentally Sensitive Areas of Nepal

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Research Article

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Abstract

The hydropower project's construction is increasing that can affect the terrestrial environment. Hydropower projects located in environmentally sensitive areas have higher environmental impacts, so I analyzed the spatio-temporal interaction between hydropower projects' locations and terrestrial environmentally sensitive areas of Nepal to visualize the probable environmental impacts. I found that most of the existing projects lie on the hill, however, future projects are moving northward. Among the 12 eco-regions of Nepal, hydropower projects are located in 10 eco-regions. Hydropower projects were found to interact with more than half of biodiverse areas of the country (28 out of 45), and more than five thousand megawatts of hydropower projects are located completely inside these biodiverse areas. The study suggests that the interaction between hydropower projects and environmentally sensitive areas might increase in the future. Hydropower projects should avoid environmentally sensitive areas such as biodiverse areas and protected areas as far as possible to minimize the impacts. Rapid hydropower development is a necessity in countries like Nepal, so further studies on the impacts of hydropower projects on environmentally sensitive areas as well as improvement of the quality of the environmental assessment of the projects are necessary for environment-friendly development.

Introduction

Renewable energy is expected to have lesser environmental impacts than fossil fuel consumption, however, there might be impacts on biodiversity and the environment during the construction and operation of the renewable energy project [1,2]. Hydropower is one of the major sources of renewable energy, supplying 16.4% of the world's electricity from all sources in 2016 (www.worldenergy.org, accessed on 2 August 2019), and its construction is increasing in the Himalayan region including Nepal [3–7] as well as other parts of the world [8–10].

The researches on various parts of the world show that hydropower projects can severely affect the environment and biodiversity [2,11–15], however, most of them focused on the detrimental effects of hydropower projects on fish diversity, richness, migration, and their important habitats [11,12,14,16–18]. The few researches that are conducted on the effects of hydropower projects on the terrestrial environment suggest that hydropower projects might affect terrestrial biodiversity and faunal species [16]. However, these studies mainly focused on direct impacts due to dams and inundation on forests [19], montane birds [20], and migration of caribou [21]. There are inadequate researches on the effects of hydropower projects' development on environmentally sensitive areas such as biodiverse areas and protected areas. Hydropower projects have a large number of structures such as dams, tunnels, canals, powerhouse, internal project roads, access roads, camps, transmission line (hydropower projects' components including associated and auxiliary structures) [22]; and most of these structures cause habitat fragmentation, that affects terrestrial faunal species and biodiversity in environmentally sensitive areas [23–28], so the study related to hydropower projects' distribution with environmentally sensitive areas is necessary.

Nepal has a high potential for hydropower projects (total 83,000 MW, technically feasible 45,610 MW and financially feasible 42,133 MW) and the requirement of electricity is increasing (up to 15,000 MW installed capacity will be required in 2030) [29]. In Nepal, about 95% of electricity, and more than 99% of renewable electricity is currently produced from hydropower projects (www.doed.gov.np, accessed on 6 Sep 2018). To overcome the shortage of electricity in the country [7] and to meet the increasing demand for electricity, the Government of Nepal has planned to accelerate the hydropower projects' development and has adopted the National Energy Crisis Reduction and Electricity Development Decade related Action Plan from 2016 that helps to increase the construction of hydropower projects.

The location of the hydropower project is an important parameter for assessing the environmental impacts [18,30]. Likewise, the spatial approach is important for estimating the impacts of hydropower projects and the distribution of hydropower projects can be insightful for estimating the probable impacts [31,32]. So, I spatially analyzed the potential interactions between current and future hydropower projects with environmentally important/sensitive areas. Hydropower projects that interacted with species-rich areas (biodiverse areas) and protected areas have higher environmental impacts [18,31]. So, my objective for this study is to analyze the numbers and capacities of existing, under-construction as well as proposed hydropower projects within geographic regions, eco-regions, and the important terrestrial habitats (environment protection area, protected areas, Important Bird and Biodiversity Areas and Key Biodiversity areas) of Nepal.

Results

Geographic and eco-regional distribution of hydropower projects

The highest number of all hydropower projects was found in the hill, however, the highest capacity of all hydropower projects was found in the mountain. The highest number and capacity of existing projects were located on the hill. Although the highest number of under-construction and proposed projects were located on the hill, the highest capacity of the under-construction and proposed projects was located in the mountain (Figure 1). Details are given in Table 1.

Out of 12 eco-regions of Nepal, hydropower projects were located in 10 eco-regions except for Upper Gangetic Plain Moist Deciduous Forests and Lower Gangetic Plain Moist Deciduous Forests. The highest capacity of the projects was located in Himalayan Subtropical Broadleaf Forests, however, the highest number of projects was located in Eastern Himalayan Broadleaf Forests. Although the highest capacities of the existing and proposed projects were found in Himalayan Subtropical Broadleaf Forests, the highest capacity of under-construction projects was located in Eastern Himalayan Subalpine Conifer Forests. While no existing and under-construction were located in Rock and Ice region, nine proposed projects with a total capacity of 566.95 MW were located in the ecoregion (Figure 2). Details are given in Table 2

Hydropower projects and environmentally important/sensitive areas

There was significant differences in number ($\chi^2 = 15.4$, df = 2, p = 0.0005) and capacity ($\chi^2 = 22.83$, df = 2, p < 0.0001) of existing, under-construction and proposed projects that were located in the environmentally sensitive areas (PIKs and CEPA) of Nepal. There was no significant difference between existing and under-construction projects that were located in environmenatlly sensitive areas interms of the number ($\chi^2 = 2.07$, df = 1, p = 0.1503) and capacity ($\chi^2 = 3.17$, df = 1, p = 0.075). However, the proposed projects' number ($\chi^2 = 6.39$, df = 1, p = 0.0115) and the capacity ($\chi^2 = 10.21$, df = 1, p = 0.0014) in environmentally sensitive areas were significantly higher than under-construction projects (Supplementary Table S1 and Figure 3).

No hydropower projects were found to be located completely within the CEPA. The total of 19 hydropower projects (total capacity 3,481.87 MW) interacted in the CEPA, and their capacity ($R^2 = 0.75$) and numbers ($R^2 = 0.59$) increased from existing to proposed projects: four existing projects (total capacity 45.02 MW), two under-construction projects (total capacity 62 MW), 13 proposed projects (total capacity 3,374.85 MW) were in the CEPA (Supplementary Table S1 and Figure 3).

Out of the 45 PIKs, 275 numbers (45.23% of the number of projects) of the hydropower projects with a capacity of 17,994.24 MW were found to be partially or fully located in 28 (62.22% of the number of PIKs) PIKs. The percentage of hydropower projects that partially and fully overlap with PIKs increased from existing and under-construction projects (40%) to the proposed project (47%). The overall number ($R^2 = 0.925$) and capacity ($R^2 = 0.893$) of hydropower projects in the PIKs were increased from existing projects to proposed projects: 29 existing (330.83 MW capacity) and 67 under-construction (3,167.03 MW capacity) to 179 proposed projects (3,496.38 MW capacity). Among those 275 projects, a total of the 150 hydropower projects with a capacity of 5,103.98 MW was found to be located completely within PIKs area; and their number ($R^2 = 0.93$) and capacity ($R^2 = 0.99$) were also found to be increased from existing to proposed projects: 16 existing (132.03 MW capacity) and 37 under-construction (1,685.37 MW capacity) to 97 proposed projects (3,286.58 MW capacity) (Figure 3).

Among the PIKs, the highest number of hydropower projects were found to be located in Annapurna Conservation Area, however, the number density (number of projects per 100 sq. km of the PIKs areas) of hydropower projects were highest in the Lantang Buffer Zone (Table 3 and Supplementary Table S1). The highest capacity, as well as capacity density of hydropower projects (capacity of projects per 100 sq. km of the PIKs areas), were in Makalu Barun Buffer Zone (Table 3 and Supplementary Table S1). Among existing projects, the highest number of projects were in Annapurna Conservation Area, however, Mai Valley Forests had the highest number density of the operated projects. The highest number, capacity, and capacity density of under-construction projects were in Gaurishankar Conservation Area, however, the highest number density of under-construction projects was in Lantang Buffer Zone. The highest number of proposed projects were found to be in Annapurna Conservation Area. Nevertheless, the highest number density, capacity, and capacity density of proposed projects were in Makalu Barun Buffer Zone. Details are given in Table 3 and Supplementary Table S1.

Discussion

While hydropower projects are considered as green development, it has several environmental problems [2,9,11,12]. Large hydropower projects have severe adverse regional environmental impacts due to secondary impacts such as deforestation, regional development, disturbance to wildlife [18,33,34]. Similarly, the cumulative effect of several hydropower projects in an area also has several adverse environmental impacts [8,14,32,35]. Likewise, noise can affect wild fauna even the infrastructure does not directly affect it [20,36]: blasting during tunnel excavation and other project construction activities of a large project or several smaller projects might severely affect in large geographical extent. So, a large number of hydropower projects or large capacity or both in an area suggest the higher adverse impacts of hydropower projects on that area.

Hydropower projects and their associated structures might have substantial impacts on terrestrial biodiversity, especially in remote locations. Hydropower projects in remote locations need to construct a long transmission line, access roads as well as electricity line for construction power. In intact remote areas, these structures might have detrimental ecological impacts [23]. My study suggests although, most of the existing projects' capacity is found in the hill, future projects' capacity is shifting northwards, towards remote mountains, and even in fragile rock and ice eco-region. In addition, the number of projects in the mountain is increasing from existing to the proposed project suggesting the northward shifting of projects. As the northern region of Nepal is fragile, less populated, and biodiverse with lots of protected areas [37–40] (Fig 3), future projects might have a higher impact on the terrestrial environment.

The finding of this study is consistent with the researches on impacts of the rapid development of hydropower projects in other countries of the Himalayan areas on the forests [19], montane birds [20], fish [3], and the overall environment [5,41], suggesting that hydropower projects severely affect the natural ecosystem of the Himalayas. This study shows that subtropical and temperate eco-regions are probably the most severely affected by the hydropower projects as there are a higher number and capacity of hydropower projects in these areas, which is similar to another study conducted in the adjoin Himalayan area that suggests hydropower projects predominantly affect the subtropical and temperate forests [16].

As PIKs are an important basis for biodiversity conservation as well as helpful for mitigating the global biodiversity loss [42–44], impact on these areas might significantly affect the conservation effort. In this study, a considerable number and capacity of hydropower projects are located in natural and fragile areas such as CEPA and PIKs, which is similar to the study conducted in the adjoin Himalayan area as well Andean Amazon areas [15,16]. These hydropower projects are expected to affect terrestrial biodiversity due to habitat fragmentation. Habitat fragmentation decreases species abundance and sometimes causes the disappearance of species [19,30,45–48]. Although few existing projects with less capacity are in environmentally sensitive areas, the number and capacity of hydropower projects are found to increase significantly in the future, expected to have severe impacts on the environment. In addition, the number and capacity of hydropower projects located completely inside the PIKs are also increasing suggesting more threats in the future.

More than half of the biodiverse areas (PIKs) of Nepal are affected by the hydropower projects, and about 40% of the existing and under construction projects as well as about 48% of the proposed projects are located in PIKs, which is higher than Amazon region [34]. The hydropower project number density in most of PIKs is higher than nearby Indian Himalayas, which suggests only 0.16 hydropower projects per 100 sq. km [19]. Both the highest number density (in Langtang Buffer Zone) and capacity density (in Makalu Barun buffer zone) of hydropower projects are located in the Eastern Himalayan biodiversity hotspot. These PIKs are mostly affected by proposed projects that suggest possible higher impacts in the future on the sensitive region if the developments are not managed.

All of the proposed projects might not result in implementation, however, they have a higher probability for implementation because the project proponent has invested in license and feasibility study, and the projects look feasible from desk study. Researches show that infrastructure development in the natural area significantly affects faunal species and biodiversity [48,49]. Hence, it is important to study the distribution of the hydropower project to know the effect on terrestrial biodiversity if they undergo construction as well as assess the future trends of probable impacts of hydropower projects in terrestrial biodiversity. As hydropower development face various environmental challenges, social conflict, seismic hazards, political challenges; risk analysis is suggested to minimize such challenges and attract investment [7,50,51]. The hydropower projects located in environmentally sensitive areas can have higher environmental conflict, and this study suggests that such conflict is going to increase in the future in Nepal. So, regulators should formulate the policy to minimize such conflict for sustainable hydropower development.

Despite some environmental concerns, renewable energy is the basis for sustainable development as well as the energy security of a country [52,53]. Although hydropower projects have the greatest impact on the environment among renewable energy [54], hydropower projects are the only energy resource that can generate electricity on a large and small scale in various parts of the country and replace fossil fuel consumption in Nepal [7]. In addition, hydropower projects are necessary for national development [52], so its construction has necessity and urgency for countries like Nepal. To minimize the environmental impact of the hydropower projects, environmental studies are conducted before implementation of the projects, however, these studies are not sufficient to analyze the impacts of these projects in Nepal as well as in other countries [55–58]. As environmental studies are analytical short-term studies that depend on scientific evidence and information; lack of information degrades the quality of environmental studies [31,59]. As managed hydropower project development helps to achieve sustainable development [7,9,60,61] and a significant number and capacity of hydropower projects are located in environmentally sensitive areas; it is necessary to conduct further studies for analyzing the impact of the projects on terrestrial biodiversity to find out the ways for sustainable development of hydropower projects with minimal compromise on the environmental quality and biodiversity.

Conclusion

Studies in other parts of the world also suggest that a higher number of projects or larger capacity of projects in the environmentally sensitive areas have higher adverse impacts in these areas [14,16,18,30,34,62]. The interaction between hydropower projects' location and terrestrial environmentally sensitive areas suggests that hydropower project development in Nepal might adversely impact the important terrestrial habitats, and the impact might have worsened in the future. It also gives the idea of highly probable affected regions, and important terrestrial habitats by providing the relative distribution of hydropower projects and capacity. As the development of hydropower projects in such critical habitats might have severe impacts on the terrestrial biodiversity, the development should be carefully planned and policy should be formed for the avoidance of these areas as far as possible. In the case of the development of hydropower projects in PIKs, the appropriate terrestrial biodiversity management plan should be included in environmental studies of the hydropower projects and strictly implemented to minimize the threats. As the development of hydropower projects is inevitable and necessary in Nepal, further researches on hydropower projects' impact on terrestrial biodiversity and its mitigation are crucial along with the improvement of the quality environmental assessment of hydropower projects to minimize such threats.

Methods

Study area

Nepal, situated in the Central Himalaya region, has an area of 147,181 sq. km and is located in Latitude 26º 22' to 30º 27' N and Longitude 80º 40' to 88º 12' E [38]. There are 12 National Parks (IUCN category II), one Wildlife Reserve (IUCN category IV), one Hunting Reserve (IUCN category VI), six Conservation Areas (IUCN category VI) and 13 buffer zones (IUCN category VI), and the country's 23.39% area is protected under these areas [63]. Most of these protected areas are distributed in northeast and southern areas, and there are few protected areas located in the hill [39,40] (Figure 3). Additionally, Chure Environment Protection Area (hereafter CEPA) extends from west to the east of the entire country, covering 12.78% area of the country, which is designed for the protection of the fragile Siwalik region especially from the landslide, soil erosion, sand, and boulder extraction, and deforestation (www.chureboard.gov.np, accessed on 6 Sep 2018) (Figure 3).

The country has a variety of biodiversity due to vast variations of altitude from 67 masl (meter above sea level) to Mount Everest, 8848 masl [38]. Nepal has divided into three geographic regions; Northern areas with a low population density that contain the Himalayas up to height 8848m called mountain; the mid-range areas with moderate population density having a gorgeous mountain, high peaks, hills, valley, and lakes called hill; and the densely populated lowlands with flat terrain called terai [37]. The eastern part of Nepal has one of the biodiversity hotspots, the Eastern Himalayan Biodiversity hotspot [64], which also makes it important from a global conservation viewpoint.

Data sources

The data and maps for the study were collected from secondary sources from 16 August to 15 September 2018. The hydropower projects' location (latitudes and longitudes), status, and capacity were collected from the Department of Electricity Development (DoED) website (www.doed.gov.np, accessed on 6 Sep 2018). Nepal's protected area information was downloaded from the ICIMOD website (www.icimod.org, accessed on 27 August 2018) and verified using WCMC/IUCN and Nepal geoportal databases. (www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas, accessed on 27 August 2018; www.nationalgeoportal.gov.np, accessed on 27 August 2018). The data for Chure Environment Protection Area (CEPA), was downloaded from President Chure-Terai Madesh Conservation Development Board, Nepal website (www.chureboard.gov.np, accessed on 27 August 2018). Nepal's geographic area data was downloaded from the ICIMOD website (www.icimod.org, accessed on 27 August 2018). The data for the eco-region was downloaded from The Nature Conservancy website (www.maps.tnc.urg/gis_data.html, accessed on 27 August 2018).

The important bird and biodiversity area (IBA) and Key Biodiversity Area (KBA) of Nepal data were downloaded from Birdlife International on request (www.birdlife.org, accessed on 28 August 2018; www.keybiodiversityareas.org/site/requestgis, accessed on 6 September 2018). Nepal administrative boundary data was downloaded from Nepal geoportal (www.nationalgeoportal.gov.np, accessed on 27 August 2018).

Data extraction

I considered the license boundary of the project issued by the DoED (for government projects that do not require a license, the coordinate listed in the DoED website was considered) as the location of hydropower projects as most of the project structures are located inside the license boundary. Although most of the previous studies on hydropower projects' impacts focus on the number of dams [11,14,16,19,33,65], there are debates about whether single large or several small hydropower projects have higher environmental impacts [8,18,32,33,35,60,62,66]. So, I considered both the numbers and total capacity of hydropower projects for this study. For this study, the projects having a capacity of one Mega Watt (MW) or more were considered, because project having capacity less than one MW does not require environmental study based on installed capacity [67], are localized and managed by local level, and expected to have minimal environmental impacts.

For the study, I considered different categories of hydropower projects as existing projects (projects that have undergone commercial operation), under-construction projects (projects whose feasibility and environmental study have completed, and acquired construction license from DoED, and also include one government under-construction project) and proposed projects (projects that have received survey license and are under study phase, projects whose study are completed and have applied for construction license; and government projects under study phase as well as the study completed but have not gone to construction phase). I did not consider projects that applied for the survey license as they are in the preliminary stage, and permission for the study has not been issued by the government.

I studied the geographical and eco-regional distribution of the project to show which areas have the highest number and capacity of the projects. In Nepal, the IBA and KBA areas are found to be overlapped. The IBA, KBA, and protected areas were merged and named as PIKs (short form for protected areas, IBA, and KBA) or biodiverse areas (Table 3) because most of the protected areas are found to be IBA and KBA, and vice versa in Nepal. The 27 IBA and KBA, and 33 protected areas (including buffer zones) were located in the country; combining them a total number of 45 PIKs or biodiverse areas were included in the analysis. The Chure Environment Protection Area (CEPA) data had been merged into a single layer from the given KMZ file, and due to its unique nature (it is not included in IUCN categories, is designated to protect the fragile environment and established under different act than other protected areas), it was separately analyzed.

Analysis

Altogether 608 hydropower projects with a total capacity of 35.98 GW were considered in the analysis. The current installed capacity of existing projects was found to be 1.01 GW (73 projects), 162 projects (5.00 GW capacity) were under-construction and 373 projects (29.97 GW capacity) were proposed.

I used ESRI Arc Map 10.3 GIS software for spatial analysis [68]. The maps were converted into Modified UTM 84 using the project tool as most of Nepal's data is in this projected coordinate system. As eco-regions have global data, I clipped them by Nepal administrative boundary to select the data related to Nepal. I conducted most of the spatial analysis between hydropower projects and environmentally important areas (PIKs and CEPA) using selection and field calculator in Arc MAP 10.3. The findings were expressed in percentage as well as in number.

The analysis for the geographic and eco-regional distribution of hydropower projects was conducted to find out the number and capacity of projects found in each region. For the hydropower projects' distribution with respect to CEPA and PIKs, the number and capacity of the projects whose project area interacted with the CEPA and PIKs areas as well as the number and capacity of hydropower projects that were completely within them were spatially analyzed using the Arc MAP. As the areas of PIKs vary greatly (less than one sq. km. to more than 7,000 sq. km), the hydropower projects' number and capacity were analyzed while considering the areas of the PIKs as the number and capacity of hydropower projects per 100 sq. km of the area (named them the number density and capacity density respectively); and compared them among various PIKs. During the analysis, if one project was located in two or more regions/areas, its capacity and number were considered in both regions/areas.

The analysis of the data was conducted in Microsoft Excel with the help of add-in 'STATISTICIAN (version 2.00.01.81)'. First, I analyzed the data normality of the capacity of projects whose project area interacted with environmentally sensitive areas (PIKs and CEPA) using the Shapiro-Wilk test as it was most appropriate to test the normality [69,70]. The data was not found to be normally distributed. In addition, the number of projects whose project area interacted PIKs and CEPA is discrete variables (count). So, I used the Kruskal Wallis H test to assess the differences in number and capacity of existing, under-construction, and proposed projects in environmentally sensitive areas (PIKs and CEPA) because this test is appropriate for non-normal and discrete data [71,72]. In addition, I used linear regression to analyze the trends of the interactions between hydropower project locations' with PIKs and CEPA to assess future interactions.

Declarations

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Author Contribution

All works for this research had been conducted by H R Ghimire.

Competing Interests

The views expressed in this article are not views of the Department of Electricity Development, Ministry of Energy, Water Resources and Irrigation, Government of Nepal. All ideas, views, and concepts presented in the article are of the author himself. None of the data and information given here is confidential, and all data are publicly available and sources are duly acknowledged in the article. The author declares no competing interest.

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Tables

Table 1: Geographical distribution of Hydropower Projects in Nepal

Geographical Areas	Existing projects		Under-Construction projects		Proposed projects		Total Hydropower projects	
	Number	Total capacity (MW)	number	Total capacity (MW)	number	Total capacity (MW)	number	Total capacity (MW)
Terai	2	16.02	3	151.3	11	1,408.16	16	1,575.48
Hill	54	837.11	103	2,013.7	201	17,679.08	358	20529.89
Mountain	24	252.16	79	3,523.91	196	19,493.48	299	23269.55

- Some projects located in two or more regions, and their capacity and number is considered in all located region in this case

Data Sources: www.doed.gov.np, www.icimod.org

Table 2: Hydropower distribution in various eco-region of Nepal

S.N.	Name of eco-region	Number of projects				Total capacity of the projects (MW)			
		Existing projects	Under-Construction projects	Proposed projects	Total Hydropower projects	Existing projects	Under-Construction projects	Proposed projects	Total Hydropower projects
1	Lower gangetic plain moist deciduous forests	-	-	-	-	-	-	-	-
2	Upper gangetic plain moist deciduous forests	-	-	-	-	-	-	-	-
3	Terai- duar savanna and grasslands	-	1	3	4	-	48	516.5	564.5
4	Himalayan subtropical broadleaf forests	46	68	101	215	729.08	1721.29	12,574.31	15,024.68
5	Himalayan subtropical pine forests	26	42	96	164	481.46	738.41	9,412.00	10.631.87
6	Eastern Himalayan broadleaf forests	33	84	138	255	355.72	2,946.55	10,819.97	14,122.24
7	Western Himalayan broadleaf forests	3	23	69	95	43.2	812.64	8,534.24	9,390.08
8	Eastern Himalayan subalpine conifer forests	7	36	129	172	101.23	2,229.75	10,888.88	13,219.86
9	Western Himalayan subalpine conifer forests	2	10	61	73	32.5	126.29	9,152.6	9,311.39
10	Eastern Himalayan alpine shrub and meadows	-	10	52	62	-	1,420.69	6,067.63	7,488.32
11	Western Himalayan alpine shrub and meadows	1	2	27	30	11.2	402.4	6,047.57	6,461.17
12	Rock and ice: Palearctic	-	-	9	9	-	-	566.95	566.95

- Some projects located in two or more regions, and their capacity and number is considered in all located region in this case

Data Sources: www.doed.gov.np, www.maps.tnc.urg/gis_data.html, www.nationalgeoportal.gov.np

Table 3: Number and Capacity of Hydropower projects per 100 sq.km of the environmentally important/sensitive areas

S.N.	Name of the environmentally important area	Type	Number of projects/100 sq.km.				Total capacity of the projects (MW)/100 sq.km.			
			Existing projects	Under-Construction projects	Proposed projects	Total Hydropower projects	Existing projects	Under-Construction projects	Proposed projects	Total Hydropower projects
1	Annapurna	CA_IKBA	0.12	0.22	0.63	0.97	1.53	15.41	89.85	106.79
2	Api – Nampa	CA	0.05	0.11	0.37	0.53	1.58	0.58	17.10	19.25
3	Banke	NP	-	0.18	-	0.18	-	8.45	-	8.45
4	Banke - Buffer Zone	NPBZ_IKBA	-	0.31	-	0.31	-	14.66	-	14.66
5	Barandabhar forests and wetlands	IKBA	-	-	-	-	-	-	-	-
6	Bardia	NP_IKBA	-	0.11	-	0.11	-	5.35	-	5.35
7	Bardia - Buffer Zone	NPBZ_IKBA	-	0.18	-	0.18	-	8.63	-	8.63
8	Chitwan	NP_IKBA	0.08	-	-	0.08	1.24	-	-	1.24
9	Chitwan - Buffer Zone	NPBZ_IKBA	0.14	-	0.14	0.27	2.06	-	6.85	8.90
10	Dang Deukhuri foothill forests and west Rapti wetlands	IKBA	-	-	0.06	0.06	-	-	22.77	22.77
11	Dharan forests	IKBA	-	-	0.12	0.12	-	-	0.22	0.22
12	Dhorpatan	HR_IKBA	-	-	0.08	0.08	-	-	69.43	69.43
13	Farmlands in Lumbini area	IKBA	-	-	-	-	-	-	-	-
14	Gauri-Shankar	CA	0.36	1.00	1.13	2.49	5.56	118.58	119.92	244.06
15	Ghodaghodi Lake	IKBA	-	-	-	-	-	-	-	-
16	Jagdishpur Reservoir	IKBA	-	-	-	-	-	-	-	-
17	Kanchanjunga	CA_IKBA	-	0.05	0.59	0.68	-	13.94	93.42	107.36
18	Khaptad	NP_IKBA	-	-	-	-	-	-	-	-
19	Khaptad - Buffer Zone	NPBZ_IKBA	-	0.37	0.37	0.74	-	0.57	102.20	102.77
20	Koshi Tappu	WR_IKBA	-	-	-	-	-	-	-	-
21	Koshi Tappu - Buffer Zone	WRBZ_IKBA	-	-	-	-	-	-	-	-
22	Krishnasar	CA	-	-	-	-	-	-	-	-
23	Langtang	NP_IKBA	0.06	0.30	0.72	1.08	1.33	30.14	45.36	76.82
24	Lantang - Buffer Zone	NPBZ_IKBA	-	2.14	2.35	4.49	-	79.74	108.04	187.78
25	Mai Valley forests	IKBA	0.99	0.49	0.86	2.34	15.59	4.55	16.25	36.38
26	Makalu-Barun	NP_IKBA	-	-	0.50	0.50	-	-	160.86	160.86
27	Makalu-Barun - Buffer Zone	NPBZ_IKBA	-	0.13	2.69	2.82	-	5.76	1615.27	1621.03
28	Manaslu	CA	-	-	0.49	0.49	-	-	105.82	105.82
29	Nawalparasi forests	IKBA	-	-	-	-	-	-	-	-
30	Parsa	NP_IKBA	-	-	-	-	-	-	-	-
31	Parsa - Buffer Zone	NPBZ_IKBA	-	-	-	-	-	-	-	-

32	Phulchoki Mountain forests	IKBA	-	-	-	-	-	-	-	-
33	Rampur valley	IKBA	-	-	-	-	-	-	-	-
34	Rara	NP_IKBA	-	-	-	-	-	-	-	-
35	Rara - Buffer Zone	NPBZ_IKBA	-	-	1.01	1.01	-	-	82.65	82.65
36	Sagarmatha	NP_IKBA	-	-	0.09	0.09	-	-	6.62	6.62
37	Sagarmatha - Buffer Zone	NPBZ_IKBA	-	-	1.45	1.45	-	-	326.85	326.85
38	Shey-Phoksundo	NP_IKBA	-	-	0.03	0.03	-	-	8.53	8.53
39	Shey-Phoksundo - Buffer Zone	NPBZ_IKBA	-	-	0.15	0.15	-	-	24.16	24.16
40	Shivapuri-Nagarjun	NP_IKBA	-	-	0.89	0.89	-	-	1.89	1.89
41	Shivapuri-Nagarjun-Buffer Zone	NPBZ	-	-	0.86	0.86	-	-	1.82	1.82
42	Suklaphanta	NP_IKBA	-	-	-	-	-	-	-	-
43	Suklaphanta - Buffer Zone	NPBZ_IKBA	-	-	-	-	-	-	-	-
44	Tamur valley and watershed	IKBA	0.07	0.60	1.27	1.94	0.37	34.61	66.03	101.02
45	Urlabari forest groves	IKBA	-	-	-	-	-	-	-	-

- The IBA and KBA are overlapped in Nepal, IKBA in the table means both Important bird and biodiversity areas as well as key biodiversity areas.
- CA- Conservation areas, NP- National Park, WR- Wildlife Reserve, NPBZ- National Park's Buffer zone, WRBZ- Wildlife Reserve's Buffer zone
- Some projects located in two or more areas, so their number and capacity is considered in all located areas in that case

Data Sources: www.doed.gov.np, www.icimod.org, www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas, www.birdlife.org, www.keybiodiversityareas.org/site/requestgis, www.nationalgeoportal.gov.np

Figures

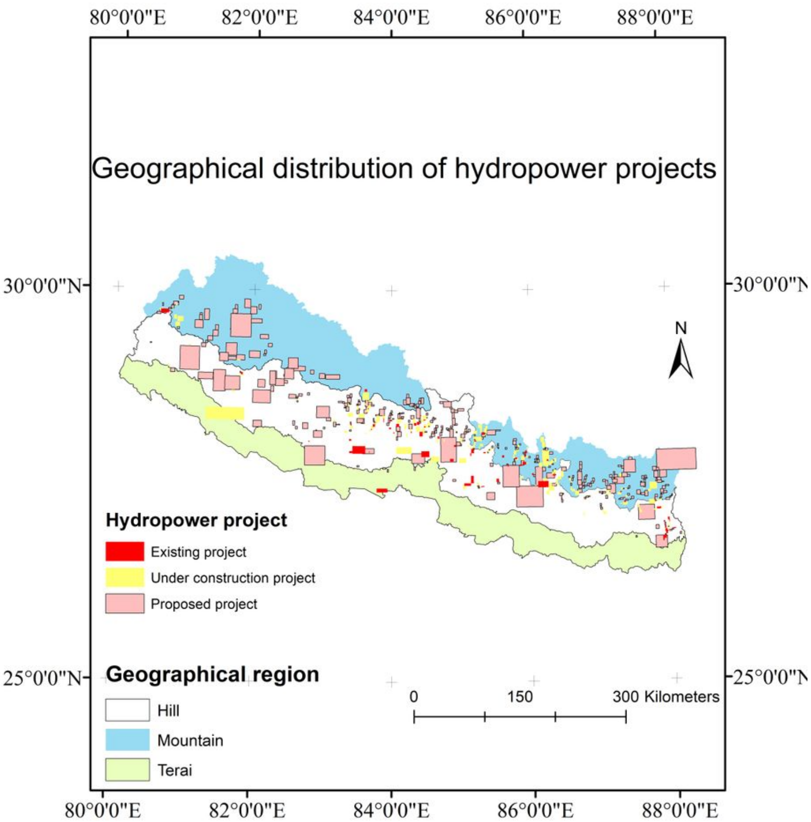

Figure 1

Geographic regions of Nepal and hydropower projects' distribution Data Sources: www.doed.gov.np, www.icimod.org, www.nationalgeoportal.gov.np

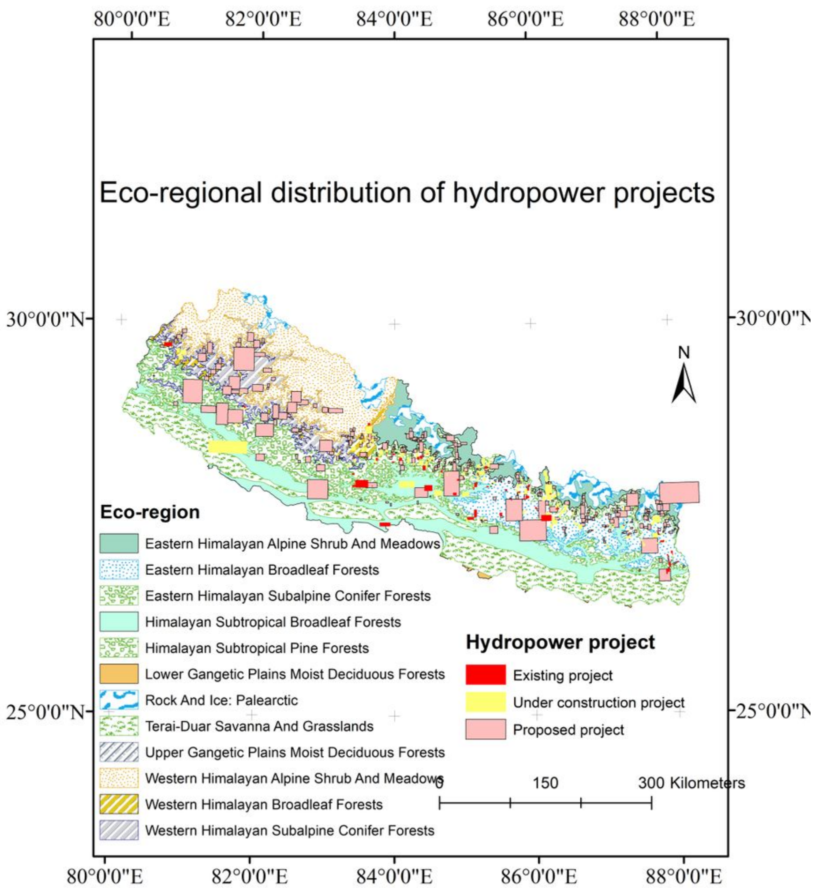

Figure 2

Ecological regions of Nepal and hydropower projects' distribution Data Sources: www.doed.gov.np, www.maps.tnc.urg/gis_data.html, www.nationalgeoportal.gov.np

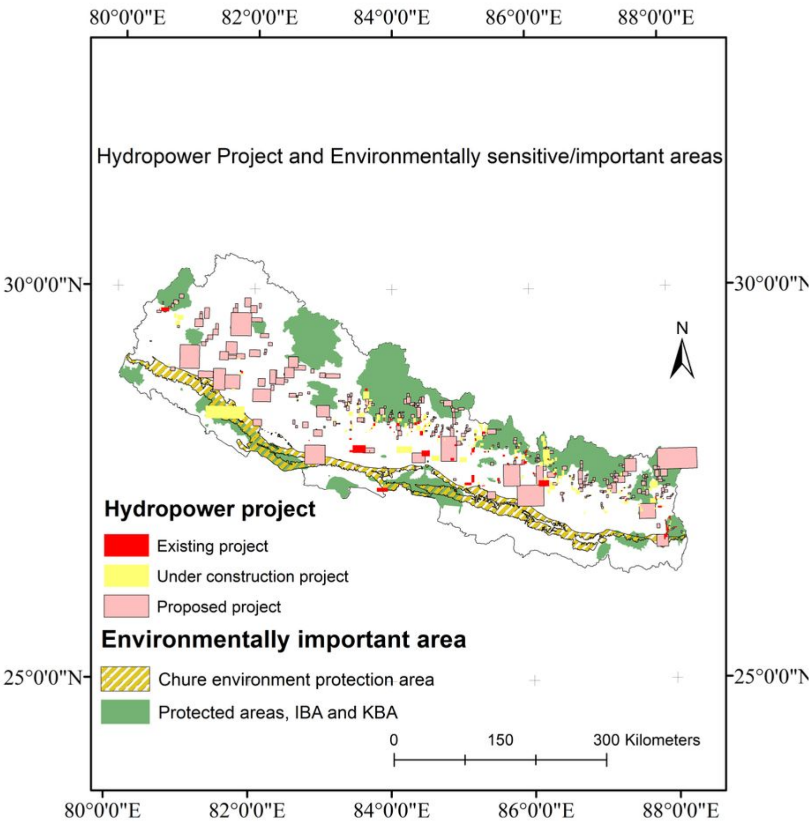

Figure 3

Distribution of hydropower projects with respect to environmentally sensitive/ important areas in Nepal Data Sources: www.doed.gov.np, www.icimod.org, www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas, www.chureboard.gov.np, www.nationalgeoportal.gov.np, www.birdlife.org, www.keybiodiversityareas.org/site/requestgis

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