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Analysis of Earthen Road Construction and Land Degradation in the Tankhuwakhola Watershed of Dhankuta District

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Abstract

Earthen road construction has resulted land degradation in the Tankhuwakhola watershed of Dhankuta district, eastern hills of Nepal. The community living near the highway has dramatically changed in their way of living with the adoption of commercial crops. As a result, the people who lived far from the access of roads have interested in the expansion of agricultural link roads to their community. The local government had prepared a District Transport Master Plan (DTMP) and identified 25 rural earthen road schemes in the Tankhuwakhola watershed. The local people have also given high priority to road construction for increasing access to markets, education, health services and other facilities. The analysis of both spatial and non-spatial data reveals that the watershed area losses 1.8 million cubic meter soils due to the cause of earthen road construction. As a result, the area is suffering from the problem of the landslide, soil erosion that ultimately result of land degradation. This paper concludes that the acceleration of land degradation has exerted to the sustainability of population-resource relation. The watershed area has been producing more profitable commercial crops for exporting outside from the hills since the construction of the Koshi highway. The watershed needs an integrated watershed management program to address human-induced vulnerability and sustainability of watershed resources.

Keywords: Environment, earthen road, land degradation, watershed management.

Introduction

The land is a primary natural resource in many agrarian countries like Nepal in which farmers use the land for crops production as well as management of forest water and biotas. Land demonstrates the subsistence for the majority of rural people in supporting the agriculture-based livelihood activities of the communities. The local communities have been changed land by the clearance of forest that drove new utilization for different purposes. Turner et al. (1995), and Ellis (2007) concluded that the drivers of land use and land cover changes are highly associated with biophysical attributes of the earth's surface and human-modification. It is mainly due to the presence of human activities has greatly been affected by the biophysical environment of a place in which local communities settled down there over centuries. These communities have brought new land permanently by the clearance of forest, carving terraces on the hill slopes and the use of technologies for transforming stock and flow of resources (Khatiwada, 2019). In this way, road construction can be considered as the tremendous causal factor of land degradation. Nowadays, land degradation is being an important issue because of the ever-expanding demands of the growing infrastructural facilities with an increasingly affluent population.

Land has become an integral part of the way of living of Nepalese people. However, the land degradation problem has been increasing and it became a very critical issue in the mountain. It is mainly related to the physical, biological and chemical processes as well as direct or indirect effects of human activities (Chalise et al., 2019). Other factors of natural calamities such as landslide, drought and flood are also frequently occurred in the various parts of Nepal. Nowadays, the flood has become a major causal factor for land degradation (Karkee, 2004). Deforestation has also considered one of the most crucial factors for rampant soil erosion (Awasthi et al., 2002). The results of their studies indicate that the rate of soil erosion varies on the basis of topography, land use and land cover changes, uneven rainfall distribution and increasing population pressure (Chalise et al., 2018). It can be argued that human practices and the introduction of machine tools and technologies in development activities have been accelerating land degradation.

The road construction is a major factor for land use land cover change as well as land degradation (Pradhan & Sharma, 2017). The increasing population pressure, rapid urbanization, improper slope cutting for road and irrigation canal constructions have exacerbated the instability of land that caused deterioration of mountain environments (Dixit, 2003). However, Gurung (1981), Gurung (1989) and Koirala (2017) have not agreed with the hypothetical and exaggerated theories of the possibility of the eco-crises and environmental degradation in Nepal Himalaya as claimed by Eckholm (1975). Patley et al. (2007) study was highly significant to the poorly constructed roads and the fatality of the landslide in Nepal, while it was connected by only footpaths due to limited economic opportunities in ancient Nepal. Nowadays, the different tiers of federal governments as well as local communities have given high priority to road construction to increase access to road transportation, market, education and health services. However, lack of proper knowledge of road engineering and local people heavily used machinery equipment for road construction have also accelerated to the landslides and land degradation (McAdoo et al., 2018). In this context, various studies' findings are significantly claimed that there is a correlation between road construction and land degradation in different parts of Nepal. For instance, the expansion of the Koshi Highway and its link roads have further sprawled new economic opportunities as well as land use and land cover changes in the Dhankuta district (Virgo & Subba, 1994). It is mainly due to the average road density of the Koshi hills observed 14.2/1000 km^2 in 2010 and it was 9.1/1000 km^2 in 2007 (Pradhan & Sharma, 2017). The rural road construction has resulted to more vulnerable to landslide and erosion in the hilly areas of Nepal (Linkha et al., 2019).

An attempt has been made to focus road construction and its impact on land degradation in Tankhuwakhola watershed area. Nowadays, the area has increasing road density and rapid changed also occurred in traditional farming systems into more profitable crops.

Methods and Materials

The study area lies in the Tankhuwakhola watershed on the eastern Hills of Nepal. Tankhuwakhola, named after the Tankhuwakhola, a sub-watershed of Tamor River and originates in the southern slope of the Tinjure-Milke Mountain Range (Khatiwada, 2019). The steep and rugged topography makes more than 95 % area of the hill-slope.

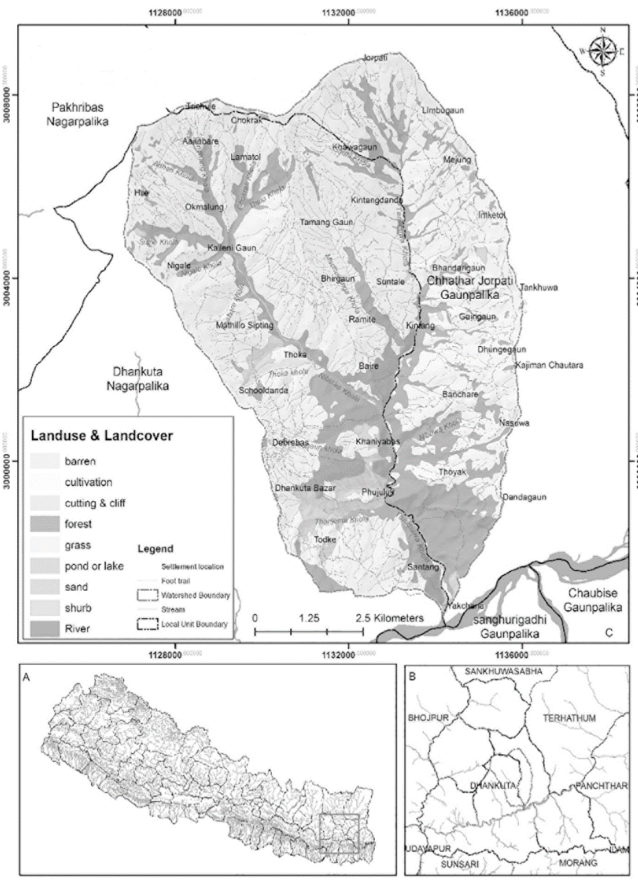

Figure 1. Tankhuwakhola Watershed Dhankuta

The study area is made with the diverse topographic features, such as *Lekh, Kachhad*, and *Besi* and comprises the narrow river valley, undulating hill slopes with flat upland terraces (*Tars*) and steep slope. Tankhuwakhola watershed has extended from 27º59' to 28˚5'10" northern latitude and longitudinal extension of 83˚41'45" to 83˚52'14"E (Fig 1). The watershed area has been surrounded by Jorpati-Guranse-Trisule in the north, Jorpati-Tankhuwa-Sibhuwadanda in the east, Hile-Dhankuta-Chulibandanda in the west, and Tamor River in the south. This watershed has covered an area of 73.93 km^2 where 75% areas of Dhankuta Municipality and about 25% of Chhathar-Jorpati Rural Municipality. The total population of this watershed was 25,583 in 2011 (CBS, 2012).

Tankhuwakhola watershed has both temperate and warm temperate ecosystems with temperatures ranging from 8 to 21^0C. The watershed has abundant natural resources including arable land, water, and forest. Decreasing air temperature usually coincides with increasing elevation, which directly influences the length of the growing season at different elevation zones. Owing to the weather conditions, cultivation activities were limited to single or multiple crops in a year.

The paper is mainly based on both spatial and non-spatial data. These data were taken from different sources and managed with ArcGIS. The layers of contour, stream, administrative boundary, foot trail and land use land cover were prepared from digital data of the Survey Department, Government of Nepal, 1997 with a scale of 1:25,000.

The non-spatial data were collected from different sources such as the Central Bureau of Statistics (CBS), Office of the Chhathar Jorpati Rural Municipality and Dhanktua Municipality. Similarly, land use is analyzed from the toposheet map of Survey Department of government of Nepal. This calculation is primarily correlated to the degree of slopes with the patches of cultivated land and seasonal road network. This study attempts to blending the empirical data with statistical measurements in this context, this study will be novelty in this area.

The eroded sediments due to degradation and erosion volume of soil materials has calculated by using the following formula; $\text{Volume} = \text{Area of Triangle} \times \text{Length}$

Or

$\text{Volume} = \frac{1}{2} \text{ x L x b x h}$ .... Equation I

Area of triangle is calculated as:

$\text{Volume} = \frac{1}{2} \text{ x b x h}$.................... Equation II

Where,

h = Average height of surface of road, b = Average (Base) width of road, L = length of road

Results and Discussion

History of road networks development in Dhankuta

The Koshi highway, also known as the Dharan-Dhanktua Highway was completed in 1982 (Pradhan & Sharma, 2017). After the completion of this highway, it connects to this area with the Tarai region. However, the Koshi Highway passes only at the north and western bordered of the Tankhuwakhola watershed to connect Dhankuta-Hile-Basantapur.

The efforts of the Koshi-Hill Area Development Project (KHARDEP) can be considered the second wave of road expansion in the Dhankuta district. The project planned to connect major market centers through road networks to improve the rural livelihoods of the people. Opening the road network from Jorpati to Chulachuli can be taken as an example in this watershed This process was continuing and the length of the road was increased in this district.

Table 1. Road length in Dhankuta (km.)

Road Class	Total Length	Black Topped	Gravel	Earthen	New Construction
Strategic Road	119	73	46	0	0
Urban Roads (DRCN)	538.1	4.8	54	430.9	48.4
Rural Roads	353.4	1.7	4	330.7	17
Total	1010.5	79.5	104	761.6	65.4

Source: DDC, 2013.

However, DDC, Dhankuta prepared district transport master plan (DTMP) in 2013 for further management of roads. The DTMP confirmed the total 1,010.5 km road by 2013 including 119 km strategic road in the district. Among these roads, DTMP defined 21 roads as District Road Core Network (DRCN) which total length was 538.1 km and the remaining 353.4 km roads were classified as village (rural) roads. DTMP had categorized these roads based on road conditions, geographical coverages as well as existing traffic flows. These DRCN roads connected to 35 VDCs (formerly district have 35 VDCs) with district headquarter. After categorization of the road as stated above, DDC had invested on these DRCN with high priorities. This effort can be considered the third wave of accelerating road expansion in this district (Table 1).

Road network in Tankhuwakhola watershed

Various roads were constructed in Tankhuwakhola that connect rural to market centers namely to Kajimane, Dhanktua, Kagate, Hile, Trisule and Jorpati. Out of 21 DRCNs, 2 major roads namely Jorpati – Chulachuli – Tankhuwa – Teliya - Tribeni road (36.5 km) and Hile Shadeswor - Madhuganga (Bhirgaun) road (18 km) consist in this watershed. Altogether, 25 roads are including one strategic road and two DRCN roads are there in the watershed. The previous discussion shows that the expansion of the Koshi highway was first increased the access of networks to connect the most populace areas outside the hills. After the construction of this highway, the watershed area has become very popular for the production of offseason vegetables and commercial crops. With increasing household incomes through market-oriented cash crops people have further demanded to increase access of road transportation. Khatiwada (2013) found that the farm-gate traders and locals have also need to obtain higher-order goods and services as well as an exchange of local farm produce since the late 1980s. Increasing access to road networks helps to promote the agro-based livelihood activities of the local communities in the Tankhuwakhola watershed. Thus, the efforts of local governments and rural people have been continuously involved in the expansion of rural road networks. The field survey data indicates that the watershed area has developed approximately 183 km of road. It increased both lengths and density of road networks which support to land degradation in this watershed (Table 2).

Table 2. Present road networks in the Tankhuwakhola watershed

Local Road Name	**Length (km)**	**Local Road Name**	**Length (km)**
Baire-Bhirgaun	3.826	Kopche-TankhuwaDandagaun	14.465
Baire-Suntale	3.147	Okmalung-Hile_Road	5.744
BhirgaunKattike-Lamatol	4.797	SantangChhagetol-Lukkuwa	2.722
Bhirgaun-Sipting-Kopche-Madhugangakhola	9.289	Schooldanda-Bhirgaun	11.995
Bhirgaun-Tamangaun	2.57	Suntale-Thoka-Kopche	11.11
Dhankuta Bazar-Jorpati (Hile-Basantapur Highway)	21.761	Suwaritol-Dhankuta Bazar	3.255
Dhankuta Bazar-Kopche	1.992	Takhuwa-Kintangdanda-Lamagaun-Hile	16.628
Dhungegaun-KajimanChautara	3.908	Tankhuwa-Ahale –Bhandarigaun	2.659
Guranse-Khawagaun-Dandakharka-Jorpati	8.141	TankhuwaBanhare-Karunje	5.813
Jorpati-Chulachuli-Tankhuwa-Dandagaun	14.212	TankhuwaImketol-Chulachuli-Limbugaun-Jorpati	10.216
Kattike-Okamalung	2.223	Tankhuwa-Sibhuwa-Thoyak	4.067
Kintang-Village Road	5.507	Yakchana -Dhankuta Bazar	8.777
Kintangdanda-Magargaun-Bagalegaun-Sinjaligaun	4.597	**Total**	**183.424**

Source: Filed survey, 2020

Table 2 shows the present road networks of the Tankhuwakhola watershed area. The road lengths range from about 2 km to 14 km. Except the Dhanktua-Hile-Jorpati-Section of Koshi Highway other 24 roads which are still under construction and earthen in nature. The haphazard carving of the road has been triggering the geomorphic hazard and processes due to slope failure, landslide and gully erosion.

Terrain features of the watershed

The topographic feature of the watershed area includes slope, aspect, altitude, relative relief and curvatures of earth surfaces (Chorley et al., 1985). These morphometric features contribute to the pace and magnitude of geomorphological processes (Ghimire, 2011) but the discharged carried by these features and processes occurred varied each other due to time and spaces. The Tankhuwakhola watershed is a sub-watershed of Tamor River. Its face extending towards north-south from Jorpati to Hile, east-west from Jorpati-Tankhuwa-Shibhuwadanda to Tamor River and west to east from Hile-Dhankuta-Chulibandanda to Tamor River.

The terrain contains a vertical slope gradient with angle 00 to 57.440. The calculated average slope angle of this watershed seemed 22.770. The upper catchment area of the watershed area such as Chanpe, Chokrak and

Figure 2. Road networks in Tankhuwakhola watershed

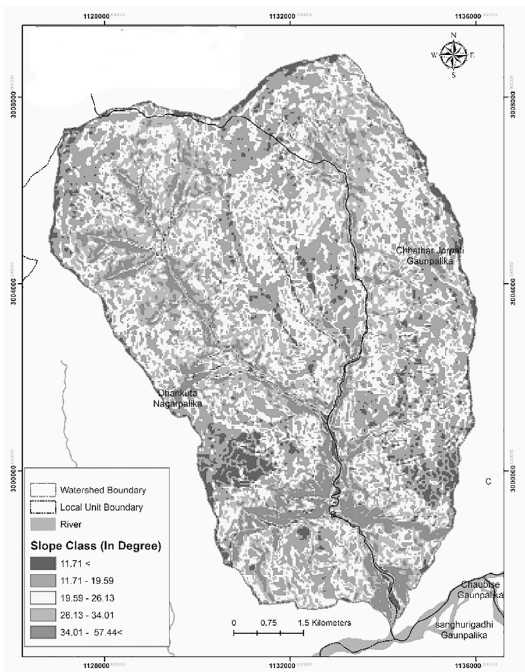

Figure 3. Slope of Tankhuwakhola watershed

Okmalung lies in the steep slope. Most of the patches of moderate and gentle slopes have been using for human settlement and terrace farming over centuries. This paper also attempts to analyze the spatial relationship between road networks and slopes. Spatial analysis shows that one-third of the total road networks extended in the steep slopes. Thus, it can be argued that the road passes through steep slopes certainly increased vulnerability. The findings of MoE (2010) have also similar to the construction of the earthen road network in a steep slope that add to vulnerability and other environmental degradation.

Estimations of soil degradation volume

This paper has also estimated the total volume of eroded or displacement sediment materials due to road construction. For this purpose, each road length was fragmented into different sections on the basis of the width of the road, the maximum height of side cutting and their slope angle. The calculated figure indicates that approximately 1,802,157.01 cubic meter soil degraded due to the construction of earthen roads (Table 3). An average cutting height of earth surfaces has depended on slope angles associated with related topography. It has also revealed that there is observed the low average cutting of soils in the settlement and a cultivated land whereas a little bit more cutting is observed in steep slope and forest area. During the field visit, the researcher found that an average of 3-4 m height and 5 m. width has cut to construct the roads. Besides road construction, other factors such as topography, forest cover, high stream density have also affected the volume of soil degradation.

The calculated discharge volume of soils/rocks of the longest earthen road extended from Takhuwa – Kintangdanda - Lamagaun to Hile (16.6 km) has depicted about 166284.07 cubic meter. The average cutting height of the earth surface, average base of the road, length of the road and volume of eroded land mass have presented in Table 3. The calculated value represents that the volume of degraded land mass is primarily correlated with the topography, slope angle, base of road and a cutting height of earth. For instance, Kopche – Tankhuwa - Dandagaun has occurred high volume of land degradation (173,579.96 m^3) as compared to Jorpati - Chulachuli - Tankhuwa - Dandagaun roads (127,911.04 m^3).

Table 3. Degradation of soils/rocks volume due to road construction

S. N.	Road Name	Average height, width and length in Meter(s)			Area of triangle (m^2)	Volume of cutting soil (m^3)
		height (h)	width (b)	length (l)		
1	Yakchana-Dhankuta Bazar	5	5	8777.05	12.5	109713.08
2	SantangChhagetol-Lukkuwa	5	5	2721.96	12.5	34024.44
3	Suwaritol-Dhankuta Bazar	4	5	3255.47	10	32554.73
4	Dhankuta Bazar-Kopche	4	5	1992.19	10	19921.93
5	Jorpati-Chulachuli-Tankhuwa-Dandagaun	3	6	14212.34	9	127911.04
6	Kopche-TankhuwaDandagaun	4	6	14465	12	173579.96
7	TankhuwaSibhuwa-Thoyak	3	5	4067.4	7.5	30505.46
8	TankhuwaBanhare-Karunje	4	5	5813.32	10	58133.2
9	Baire-Suntale	5	5	3147.13	12.5	39339.13
10	Dhungegaun-KajimanChautara	5	5	3907.89	12.5	48848.64
11	Suntale-Thoka_Kopche	4	5	11110.03	10	111100.26
12	Kintang-Village Road	5	5	5507.09	12.5	68838.63
13	Bhirgaun-Sipting-Kopche-Madhugangakhola	5	5	9289.21	12.5	116115.18
14	Takhuwa-Kintangdanda-Lamagaun-Hile	4	5	16628.41	10	166284.07
15	Schooldanda-Bhirgaun	5	5	11995.34	12.5	149941.8
16	Tankhuwa -Ahale-Bhandarigaun	5	5	2659.29	12.5	33241.13
17	Bhirgaun-Tamangaun	4	5	2570.05	10	25700.47
18	Okmalung-Hile_Road	5	5	5743.66	12.5	71795.74
19	Bhirgaun -Kattike-Lamatol	4	5	4797.07	10	47970.69
20	TankhuwaImketol-Chulachuli-Limbugaun-Jorpati	5	5	10215.71	12.5	127696.41
21	Kattike-Okamalung	4	5	2223.27	10	22232.71
22	Kintangdanda-Magargaun-Bagalegaun-Sinjaligaun	5	5	4597.26	12.5	57465.69
23	Guranse-Khawagaun-Dandakharka-Jorpati	4	5	8141.28	10	81412.82
24	Baire-Bhirgaun	5	5	3826.38	12.5	47829.8
Total		106	122	161663.8	268.5	1802157.01

Source: Calculation by authors

Consequences of land degradation on environmental resources

This paper attempt to analyze the consequences of land degradation on environmental resources in the Tankhuwakhola watershed area. Table 3 reveals the different parameters of earthen road construction which are playing a significant role in accelerating landslide and soil erosion. The incident of landslide and soil erosion has affected settlements, farming and other environmental resources. As a result, the proportion of sediment released by earthen road construction has brought a crisis on the resilience of the watershed environment. However, all these computed values indicate that Tankhuwakhola is one of the less vulnerable watersheds as compared to other watershed areas in the middle Hill of Nepal (Siddique et al., 2012). Although, the incidence of land degradation has been increasing due to losses of climatic factors especially over-rainfall and floods by the further extension of earthen roads. The faulty methods of soil management after the side cutting and lack of well-maintained drainage systems and retaining walls have accelerated to landslide, gully erosion, mass wasting and rockfall. The sediment released from the earthen road construction has deposited into the lowland (*Besi*) area which damage to agricultural lands as well as products and productivity of crops. Thus, the watershed has made more vulnerable and geomorphic hazards in the watershed. The impact of road construction has been significantly affected people's resources relationships in terms of their stock and flow to address the urgent needs of the growing population. This paper has calculated the people-resource relationship in terms of population size and existing land use in the watershed area (Table 4).

Table 4. People and resources relationship in the Tankhuwakhola watershed

S. N.	Name of Local level	Ward	Cultivated land (ha.)	Forest (ha.)	Population	Population density (agriculture)	Population density (forest)
1	ChhatharJorpati RM	2	403.38	254.52	2565	6.4	10
2	ChhatharJorpati RM	3	1228.86	765	2018	1.6	2.6
3	Dhankuta Municipality	1	385.92	160.11	4856	12.6	30.3
4	Dhankuta Municipality	2	1663.92	434.07	4597	2.8	10.6
5	Dhankuta Municipality	3	513	136.89	1525	3	11.1
6	Dhankuta Municipality	4	194.4	161.19	3284	16.9	20.3
7	Dhankuta Municipality	5	144.81	242.19	2568	17.7	10.6
8	Dhankuta Municipality	7	52.83	27.45	2231	42.2	81.3
9	Dhankuta Municipality	8	324	177.21	1939	6	11
Total 25,583			4911.12	2358.63	25583	5.2	10.8

Source: CBS, 2014

Table 4 shows the people and resources relationship in the Tankhuwakhola watershed area. The figure reveals that out of the total land, agricultural land comprises about 4,911.12and 2,358.63 hectors by forest. It supports about 25,583 populations with an average 5.2 population density in agricultural land and it was 10.8 for population density in forest land. Thus, the watershed area requires a comprehensive and integrated land management policies to address the problems of land degradation due to earthen road construction. It can be argued that human-induced factors are more significant to the degradation of environmental resources in this watershed and it is correlated with the similar studies of Gautam et al., (2003); Gurung, (2004); Chidi et.al., (2019); Chalise & Khanal, (1997); Gerrard & Gardner, (2002).

Conclusion

Land is an integral part of human settlement, farming and other developmental activities. The federal governments of Nepal have given high priority to the construction of roads to link to each ward of the *Gaun* (Rural Municipality) or *Nagar palikas* (Municipalities). This effort has also made by local governments in the Tankhuwakhola watershed area to increase access to markets, education and health services. The increasing access to roads has dramatically changed in both income opportunities and soil degradation. The incident of soil degradation has also highly increased the vulnerability and resilience of the livelihoods of the communities of the watershed. As a result, the local communities suffering from the inappropriate engineering designs in height cutting, retaining wall construction and drainage construction while they construct roads. It shows that lack of proper knowledge regarding road construction accelerated massive soil degradation and ultimately affected environmental resources. In this context, integrated watershed management plans should be developed to address human-induced hazards and sustainable uses of watershed resources.

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