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Flood Loss Assessment - A Case Study of Dordi Basin, Gandaki, Province

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Abstract

Hydropower plants are a quintessential source of clean and economical energy, serving as the primary preference for renewable energy technologies for many governments owing to their unparalleled ability to deliver dependable baseload power with negligible fluctuation. However, despite their numerous benefits, the construction and operation of these plants pose a significant threat to the population living in the river basin and the equipment involved. The damage caused by flooding can have devastating and long-lasting impacts on the area, leading to severe economic losses and a prolonged period of recovery. In the case of the Dordi Rural Municipality, a study was carried out, which revealed that the Upper Dordi Hydropower Plant Headwork and Super Dordi Hydropower Plant inlet were ravaged by a ruinous flood, which resulted in the loss of twenty million equipment and eleven workers die. The cause of the flood was attributed to the upstream landslide blockage, which eventually led to the sudden bursting of the blockage and subsequent flooding. While the compensation of the workers was provided by the District Administration Office, Lamjung, and Dordi Rural Municipality through their incurrence policy, the study underscores the urgent need to establish a highly frequent flood warning system to alert the hydropower station and the local community. Additionally, the scouring and deposition process in the river channel was observed in detail, and the data analysis indicates no significant relationship between discharge and rainfall, emphasizing the importance of proactive measures to prevent future flooding events.

Keywords: *Channel, Damage, Hazards, Landslide, River*

Introduction

In many river basins with emerging economies, rising energy demands and campaigns to reduce fossil-fuel dependence have prompted the rapid expansion of hydropower (Zarfl et al., 2015; Zhang et al., 2017). Hydropower development, which could increase by over 70% in developing countries in the next few decades (Zarfl et al., 2015; IEA, 2016), is threatening ecosystems in basins with some of the greatest aquatic biodiversity (Winemiller et al., 2016). The basin's hydropower reservoir storage, which may upsurge from ~2% of its mean annual flow in 2008 to ~20% in 2025, is diminishing seasonal flow variability downstream of many dams with an integral powerhouse and large storage reservoirs (Hecht et al., 2019).

Nepal is one of the rich in hydro-resources, with one of the uppermost per capita hydropower potentials in the world. The estimated theoretical power potential is approximately 83,000 MW. However, the economically feasible potential has been evaluated at approximately 43,000 MW (Malla, 2013). Nepal has brilliant high potential for renewable water resources, possessing about 2.27% of the world's freshwater resources (Malla, 2013). Most of the rivers flowing from Nepal Himalayas covers 818,500 ha land area equivalent to 5%, of the total surface area of the country (Bhandari, 1992). The annual average discharge of the Nepalese rivers is about 7124 m^3/s including the total basin area and about 5479 m^3/s excluding the area outside of Nepal (Malla, 2013). River flood occurs when a river overspills its banks; that is when its flow can no longer be contained within its channel.

Flood hazards are worldwide considered one of the most significant natural disasters in terms of human impact and economic losses (Jonkman, 2005). The objective of the study is to assess and performs the impact of river flooding on the Upper Dordi hydropower project. Hydropower systems alter flow conditions in the downstream river reaches regarding both seasonal distribution and seasonal volume.

Materials and Methods

Study Area: Dordi River is a perennial snow-fed river located in Gandaki Basin in the Gandaki Province, Nepal. It is the tributary of the Marsyandi River. In the river channel alltogether four Hydropower Projects (HPP) are ongoing i.e. Himalayan HPP (27 MW), Dordi 1 HPP (10.3 MW), Upper Dordi HPP (21 MW) and Supper Dordi (49.6) the average gradient of Dordi River is 15%. The study was conducted in the Super Dordi HPP and Upper Dordi HPP. It lies in Dordi Rural Municipality, Lamjung District (Figure 1).

Methods

There are two ways of doing research: qualitative and quantitative methods in research (Crotty, 1998). In this study, both qualitative and quantitative methods have been applied. The study area was selected based on the flooding issues occurring every year and the heavy loss and damage faced by hydropower plants in the Dordi River. The field survey was conducted in last early months of 2020. The measurement of the cross-section and width, of the river channel, was carried out every 100 m difference. The thickness of deposition and scoring of the river channel was observed.

Meteorological data, particularly rainfall and temperature of the nearest station Khudi Bazaar (Index No.802), and discharge data (Index 349.6) were collected from the Department of Hydrology and Meteorology, Government of Nepal. The social data was collected from the Dordi Rural Municipality whereas focal group discussions (FGDs), and Key Informant Information (KII) were conducted. Data collected using different tools were first organized into an Excel sheet so they could be systematically analyzed in detail. Economic loss caused by flood is estimated by the cost of

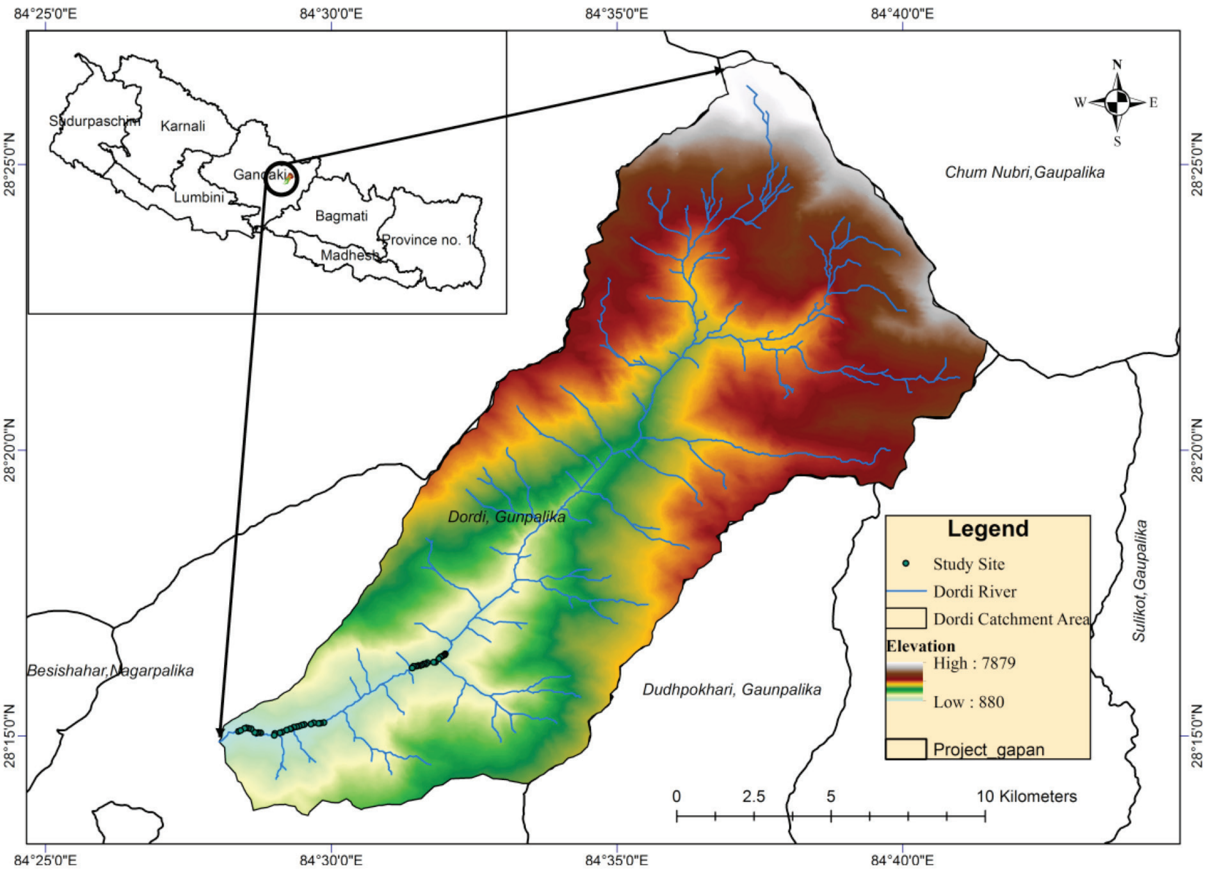

Figure 1: Map showing the Dordi river basin at Lamjung District in Gandaki Province.

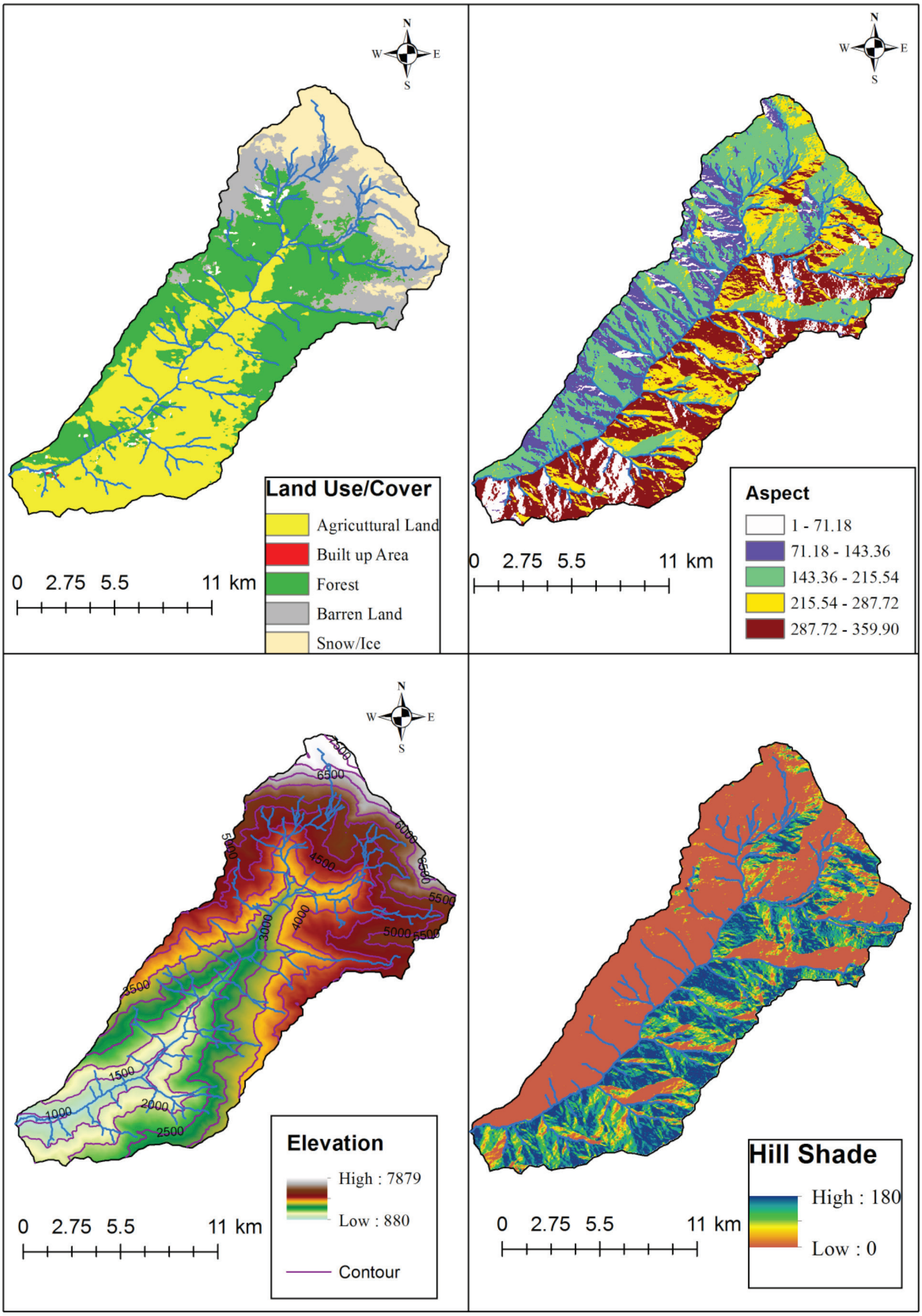

Figure 2: Dordi basin map of land use/cover, aspect, contour, and hill shade.

construction and instrument cost provided by the hydropower company. The data were analyzed by linear regression, bar -diagram, and scatter plot, and compare different variables by using Microsoft Excel 2016, ArcMap 10.2.1, and R studio.

Results and Discussion

Temperature and Rainfall

The average maximum temperature of 1988-2018 shows an increasing trend of 0.043°C/year, whereas the minimum temperature is in decreasing trend by -0.006°C/year. It reveals that those summer months are going hotter while winter months are going colder as shown in Figure 3. Similarly, rainfall data (1988-2018) indicated a decreasing trend. The maximum rainfall was observed in 1996 with a value of 4445.7 mm and the minimum rainfall was in 2014 with a value of 2070.3 mm. The trendline shows a decreasing trend of 15.7 mm per year (Figure 4). In the case of monsoon and winter months are taken while June, July, August, and September have been taken as monsoon months, and January, November, and December are taken as winter months. Monsoon rainfall is in decreasing trend of 14.36 mm per year whereas winter rainfall is slightly in an increasing trend by 0.57 mm per year.

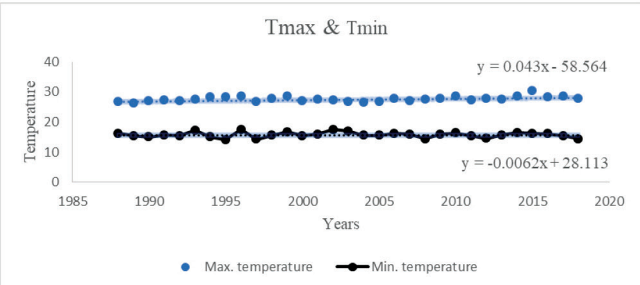

Figure 3: Maximum and minimum temperature trend (1985-2018).

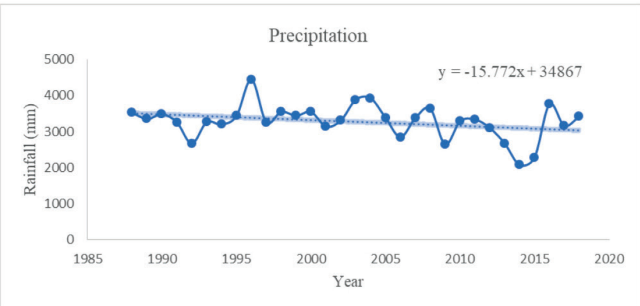

Figure 4: Annual Rainfall of 1985-2018 Dordi Basin.

Rainfall Discharge Relationship

Linear regression was applied to the relationship rainfall between and discharge. R-squared is a statistical measure of how close the data are to the fitted regression. The r-square value was 0.05, which illustrates that there is no relationship between discharge and rainfall. It showed that in heavy rainfall time, there was no high discharge rate. The relationship between the discharge and days shown in hump-shaped that the 25 July 2020 had peak discharge i.e. 338 m3/sec. It showed river was changeable in nature there is no sign of early flooding. Sudden rise discharge of the dordi river May landslide blockage in the upper stream; the burst accidentally and flood occur in the lower region of the hydropower dam construction site.

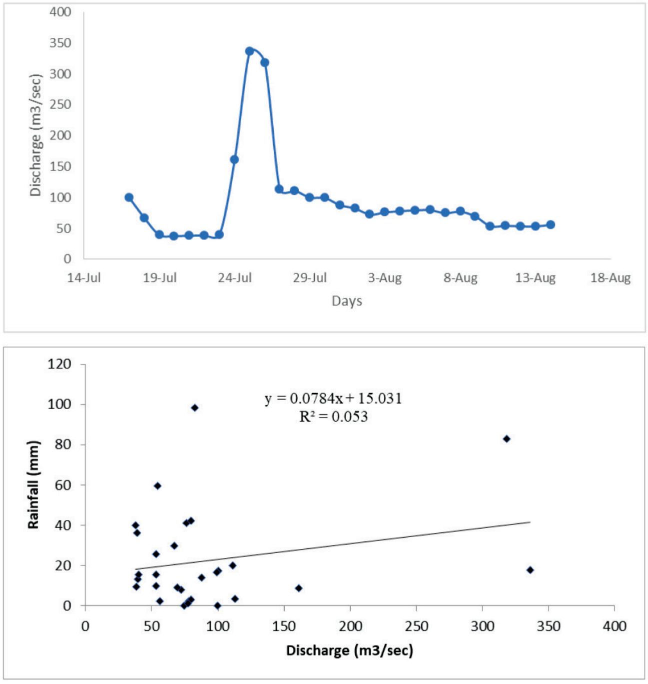

Figure 5: Relationship between (A) Discharge and days (14^{th} July to 18^{th} Aug 2020) (B) Rainfall and Discharge (14^{th} July to 18^{th} Aug 2020)

Channel Morphology

In nature, different river patterns occur but not all river patterns have an alike frequency of occurrence. R squared value of the optimum channel was 0.28 which means independent variables were correlated with the dependent variable. It shows that the optimum channel increases in a 2.32 m in every hundred meters. Cross sections are used to define the shape of the stream and its characteristics, such as roughness, expansion and contraction losses, and ineffective flow areas Channel erosion occurs by two separate processes, entrainment of channel bed sediment (scour) or mass wasting of channel banks, which consequences in channel banks collapsing into the channel bed. Channel scour happens when shear stress, controlled by channel slope and flow depth, exceeds the critical or threshold shear stress required for channel bed sediments to be trained.

The substantial widening of the Dordi channel during the flood of July 2020 was a typical morphological change caused by extreme floods in Mountain Rivers (Fuller, 2008; Krapesch et al., 2011; Nardi and Rinaldi, 2015). However, local conditions exerted a considerable stimulus on the spatial pattern of the river spreading. The alternation of short, channelized ranges where the channel width increased fewer and of longer, unmanaged reaches with the larger width increase markedly amplified downstream differences in active channel width in comparison with the pre-flood situation. Moreover, the largest increase in mean channel width and in the width, variation took place in the stretches in which the river is unconfined and its channel is entirely formed in alluvium. Channel scours are velocity-dependent and are extreme during large streamflow events. Several studies established that erosion in confined channel sections during bulky floods led to major changes in channel configuration (Fuller, 2008; Thompson and Croke, 2013). Several studies demonstrated that erosion in confined channel sections during large floods led to major changes in channel configuration (Fuller, 2008; Thompson and Croke, 2013).

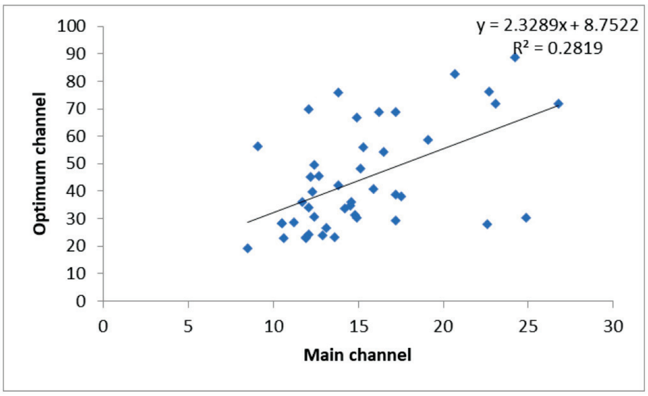

Figure 6: Relationship between an optimum channel and main channel.

Loss Damage

Natural causes of flooding in Nepalese rivers comprise fragile geological conditions, extremities in climates, topographical extremities, and seismic activities. The anthropogenic causes of flooding include socio-economic changes (population growth, poverty, and illiteracy), deforestation, unscientific agricultural practices, Land use changes, and other developmental activities. The real amount of flood damage generated by a specific flood happening is time and again a driving force that stimulates politicians to strengthen flood policy measures usually soon after flood events. It encompasses a wide range of harmful effects on humans, their health, and their belongings, on public infrastructure, cultural heritage, ecological systems, industrial production, and the competitive strength of the affected economy. Some of these damages can be specified in monetary terms, others – the so-called intangibles are usually recorded by non-monetary measures like the number of lives lost or square meters of ecosystems affected by pollution. Flood damage effects can be further categorized into direct and indirect effects. Direct flood damage covers all varieties of harm that relate to the immediate physical contact of flood water to humans, property, and the environment. Nepal is one of the most disasters prone countries to climate change and experiences frequent landslides, debris flows, and floods because of its varied topography and geological characteristics, together with torrential rain during the monsoon season. National estimates in Nepal suggest that flood events have on average killed almost 200 people and caused $35 million worth of damage every year since 1980. Low economic strength, inadequate infrastructure, low-level of social development, lack of institutional capacity, and higher dependency on natural resource makes the country vulnerable to change in a climatic system including variability and extreme events. Figure 7 shows the upper dordi hydropower, headwork construction site seven workers were killed, and five labour missing in the flood, and the estimated cost for reconstruction is $1,980,000. According to focal group informants and public perception in the afternoon, time flooding happened and the working condition of workers at the dam site was swept.

Conclusion

The extreme flood of July 2020 of the Dordi River changes the river morphology, and loss of flood in Super Dordi and Upper Dordi hydropower in Gandaki Province. The river morphology confirmed the ability of high-magnitude floods to considerably broaden the channels of Mountain Rivers. However, the pattern of the river widening reflected the legacy of hydropower as well as human impacts on the Dordi River. It revealed that the abrupt release of water is not due to normal operation at the hydropower stations in the Dordi River, but is due to sudden discharges at the rupture of blockage of the landside. From the analysis there is no relationship between rainfall and discharge, data analysis shows that discharge suddenly upsurges.

Acknowledgement

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Figure 7: Comparative photographs of hydropower site before and after the flood.