Hydrological and Geological Analysis of Cohesive Soil and its Potential Risk in Middle Mountain Region: A Case Study of Naunuko Pahiro along Madi River, Kaski, Nepal

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ABSTRACT

Middle Mountain region of Nepal is most often vulnerable in hydrological and geological aspect. Rainfall pattern, runoff, infiltration rate, different losses and soil parameters of cohesive soil (Silty clay) along with slope of slide (i) and depth of slide (H), factor of safety (F.O.S) along with probabilistic approach (correlation) are decisive factors pertaining to re-occurrence of landslide. Rainfall intensity, catchment area(A), runoff coefficient plays vital role in the estimation of flood frequency over a various period of time (25years,50 years and 100years) respectively. The civil engineering structures along with middle mountain river are always vulnerable. Hence, its risk identification is prerequisite which is encompasses in the study. This study include hydrological and geological analysis of Taprang landslide (Naunuko Pahiro) which prevail at middle mountain region at an elevation ranging from 937m to 1047m of Kaski district, Gandaki Provenance , Nepal. Soil test data, rainfall data, probability and statistical approach along with different empirical formulas are used to analyse hydrological and geological hazard. Factor of safety (F.O.S) is calculated on the basis of altering value of slope of slide (i) and depth of slide (H) from slope ranging 50^0 to 70^0. With increase depth of slide greater than 10m, F.O.S. is less than one which is unstable. The slope stability found to be critical at depth of slide10m with 50^0slopes.Higher ground water table, higher rate of run-off with an average rainfall 446.50cm and higher shear stress contribute to risk of landslide along with increase discharge at down- stream of landslide with possibility of flood hazard at Madi river bank.

The result would give insight on nature of landslide and flood discharge which could support Madi Village Municipality, as well as other rural Municipality of middle mountain region of almost same elevation consisting of cohesive (Silty Clay) soil for shaping disaster risk reduction policies and strategies such that death and injuries as well as impact on civil engineering structures can be minimized.

KEYWORDS

Cohesive soil, Factor of safety (F.O.S), Flood frequency, Geological hazard, *Madi* River, Taprang landslide (*Naunuko Pahiro*), Probabilistic approach, Rainfall-runoff

INTRODUCTION

Background

Landslide is devastating natural disaster which can cause huge loss of life and property and its impact in the country like Nepal is increasing with time. (Baral, 2012). Torrential rains battered Nepal, causing widespread flood and damage to critical infrastructure. Four people were killed in landslides and floods in

Sindhupalchowk district, 30 km east of Kathmandu, three killed in Dottie and one each in Saptari, Kavre, Gorkha, Kaski, Argakhanchi, Palpa, Pyuthan, Jumla, Kalikot, Bajhang and Bajura district and one went missing from Bajura.The dam of an under-construction bridge in Kanchanpur has been washed out/away by a flooded Mahakali river. The flood has caused loss of billions of worth properties in the country.

On the basis of compiled and analysed data for the period 1978-2005, suggests that there is a high level of variability in the occurrence of landslide from year to year and overall trend is rising. It is clear that in recent years the number of fatalities has increased dramatically due to the effect of monsoon cycle. The increasing trend in landslide results from the land-use change, rural road building programme and its attendant changes to physical and natural systems. Hydrological and geological hazard are leading cause which results in the loss of farming land, agricultural production, livestock, homes, villages and road networks in middle mountain region of Nepal.

Nepal is a mountainous, least developed country, sandwiched between the Indian and Himalayan tectonic plates. In Nepal geological hazard and flood hazard represent a major constraint on development, causing high levels of economic loss and substantial fatalities each year. At least 75% of geological hazard (landslide) caused by natural movement of land tends to hydrological hazard (flood) in mountainous rivers of Nepal. The landslides may also cause by erosion of land by rivers, small or large earthquake, the result of melting glaciers and type of soil especially cohesive soil like Silty Clay in middle mountain region of Nepal. (Baral Prakash 2012) Hundreds of people died every year from flooding and landslides during Nepal's monsoon season which typically starts in June and ends in September.Widespread landslides triggered by heavy rain occurred in Shyanja District (Gandaki Provenance) and Palpa District(Province No.5) resulting in casualties and damage. According to the Nepal Disaster Risk Reduction Portal, in Shyanja District 9 people died in Waling municipality and one person was missing after a separate event in Kaligandaki Rural Municipality. Similarly, one person died and 5 people were missing in Rambha Rural Municipality (Palpa District). Furthermore 6 houses have been fully damaged across the affected Districts. Since the beginning of the monsoon season total of 288 people have died following landslide events.

Statement of the Problem

The Taprang landslide also known as Naunuko Pahiro.The study area lies between Sodha Bazaar and Chansu Bazar in the Northern part of Kaski district with an elevation of 947m and 1037m.The Tap rang landslide is the old slide which was activated on 2039 B.S. But it again re-originated on date 2067/04/18 at sharp 8:45 A.M. as huge water induced disaster. The flow of the Madi River was totally obstructed about 4 hours 20 minutes due to the mass of the landslide debris. After only at 1:05 P.M. the flow of the Madi River was overtopped on the left bank which was at low level. The Kahukhola Dudh Pokhari rural road about 1500m in length was blocked. A water pond was formed in the upstream near Seti khola village with a size of about 500m*250m approximately. Altogether five people were found to be missed along with a loss of approximately 2010 ropani of land with 134 houses. Various Governmental as well as social organization were at risk situation. Suspended bridge near Chansu Bazar of about 50m span connecting Chansu-04 ward and Namarjung-07, 08 wards were critical due to tilt of the bridge after a landslide. Landslide (debris) flows within the study area were found to be in lateral movement. Farmlands have been changed to barren and bushy land. Many cracks were observed and the slope was unstable. Thus, the cultivation of the lands was found to be impossible. The forest encroachment, haphazard grazing, slash and burn farming have accelerated the water induced disasters. In many places, failure of rural road section due to scouring of riverside slope of the road by Madi river have been observed (Baral, 2012).The Himalaya of Nepal are very vulnerable to natural and common hazards such as landslides, debris flow and soil erosion primarily triggered by extensive rainfall of monsoon. The combination of weak rocks, thick soil and monsoon climate makes each physiographic zone of Nepal very hazardous.(Dahal et al., 2006).Rugged topography, weak geological formation, active seismic conditions, occasional landslides and debris flow, glacier lake outburst, concentrated monsoon rain and unscientific land utilization are major reason for water induced disaster. Asia continent is much affected by flood induced disaster. Countries like India, China, Philippines, Iran, Bangladesh and Nepal are extremely vulnerable regarding this aspect (Shrestha et al., 2020).The hydrological and geological analysis for this severe disaster regarding its reoccurrence and possibility of risk in civil engineering structure in middle-mountain seems essential at present for sustainable stability and safety in long run.

Literature Review

Nepal is located in the heart of the Himalayas and occupies nearly one third of the main mountain range. About 83 percentage of the country is in mountainous terrain and the remaining 17 percentage the south Indo-Gengatic plain, the Terai. Owing to the rugged mountain topography, complex and fragile nature of the geological structures, soft soil cover, high intensity rainfall in the monsoon season, the mountains in Nepali Himalayas are vulnerable to geological hazard like landslides, debris flows, soil erosion, and other mass wasting phenomena leading to hydrological hazard (flood). The Himalayan rivers and streams, with their steep gradient and swift water flows, contribute significantly to the process of mass wasting in the region. (Baral, 2012)

Khale, Armana, Gairiswanra Kolpata, Ghaiyara, Karkineta, Arghaudi, Jharlangdi, Kharibanjyang, in the lower reaches of the Andhi Khola and on Siddhartha highway large landslide occur. The change in slope gradient (owing to river undercutting, bank scouring by debris flow, or human activity), heavy monsoon precipitation, and saturated slopes with groundwater are the major factors leading to slope failure. (Dhittal, 2002).

The topography of Nepal constitutes of Terai which lies to the south of the Churia (Siwalik) hills and is a generally flat land with an elevation not exceeding 200m.The Churia hill is situated in the north of the Terai. They rise to altitude from 200m to 1500m. Soil like sandy, thin and erodible is existing in this area. The midlands, with an average width of 60km were situated south of the great Himalayan range. They consist of low hills, river valleys, tectonic basins and peaks up to approximately 3000m (Figure 1). In this area the large valleys of Kathmandu, Banepa, Panchkhal and Pokhara were situated. It has great variety of soil type ranging from ancient river terraces to deeply weathered residual soil. Over grazing, forest degradation due to exploitation of copper and iron resources and overpopulation were causing serious ecological problems in this region.

The high mountains are situated north of the Middle mountain without a clearly defined boundary. This region reaches altitude of 4000m and more which is the upper limit of agricultural production. Rivers traversing the region tend to develop deep incisions. The highest peaks of Nepal found within the high Himalaya. The climate is predominately arctic with many glaciers. In some valleys cultivated land is found. (Baral, 2012)

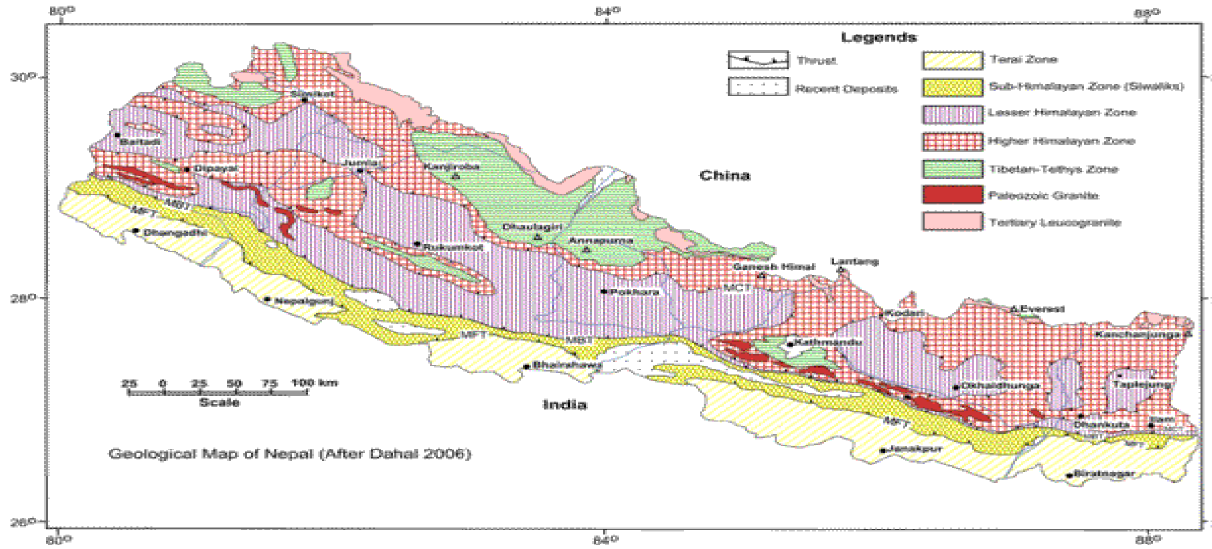

Figure 1: Geological Map of Nepal
(Source: Dahal et al., 2006)

More than 70% of our earth surface is covered with water. Scientists estimates that the hydrosphere contains about 1.36 billion cubic kilometres of this substance mostly in the form of liquid that occupies topographic depression on the earth. The water and its activity within this dynamic earth are generally called as hydrological process. During hydrological cycle; water is stored temporarily in the ground, of course in the oceans, lakes, rivers and glaciers. Evaporation, transpiration, precipitation and infiltration are the key processes involved in hydrological cycle. Precipitation includes rainfall, snowfall, hail, sleet, glaze, frost and dew. Rainfall is light if not more than 2.5mm (0.10 in) per hour, heavy if more than 7.50mm (0.30 in) per hour and moderate between this limit.(Dahal et al., 2006)

Greater the precipitation than the combine effect of infiltration rate of the surface, evapo transpirations and initial losses, runoff of overland flow will occur. Direct run off enters the stream immediately after precipitation and base flow is the late flow that enters a stream or river essentially as a ground water flow. Types of precipitation, intensity of rainfall, distribution of storm intensity on the basin, direction of storm movement, soil moisture effect evaporation and transpiration which are considered as water losses. Land use, type of soil, area, shape, elevation, slope, orientation, type of drainage net, extent of indirect drainage, artificial drainage affects the runoff process respectively. The movement of water into the soil layer plays a significant role in surface runoff process. High intensity of rainfall leads to both surface runoff and recharge of groundwater. At ground water zone which is also called as permanent saturation zone water seeks its own level and it will flow from high water levels to low water levels at certain time of concentration which increases the discharge at river bed and finally water level get raised to bank which leads to flood hazard in middle mountain region of Nepal. (Gupta et al., 1999).

Geological material at Middle mountain region of Nepal consists of Silty clay. Alluvium cannot transmit significant quantities of water that is impermeable rather than sand and gravel alluvium, sandstone and fractured limestone or limestone with caves.

Major river system of Nepal includes Koshi, Gandaki and Karnali. Those consist of a major river together with several major tributary rivers and many small tributary rivers and streams. Three major rivers: Karnali, Gandaki and Koshi join the Ganga River in the North Indian Plains. Because of scanty precipitation in Tibet, the contribution from the Tibetan portion of these river basins is not considerable. Besides these three major basins, there are also three important rivers which originate in the mid-lands of Nepal and flow through the Mahabharata and Siwalik ranges in Southern Nepal. These are Rapti, Bagmati and Kamala .

During monsoon season, frequent floods occur in these rivers which cause havoc in the Terai belt of Nepal, Uttar Pradesh and Bihar plains of India (Dahal et al., 2006)

Hydrological hazards which includes flood. That is a very large amount of water which over-flowed from a river onto a previously dry area along riverside. Heavy rainfall, runoff, and infiltrate water after saturation of ground water table including landslides which frequently occur in middle mountain region of Nepal in cohesive soil (Silty Clay) leads to frequent flood hazard in Nepal. Rainfall flooding, snowmelt flooding, ice jam flooding, dam flooding and Glacial Lake outburst flood (GLOF) are some common type of flooding. Among all mostly rainfall flooding and landslide dam flooding are most commonly observed flooding in the Middle mountain region of Nepal with sometime glacial lake outburst flood (GLOF). (Dahal et al., 2006) Madi River had also been damned by huge landslide called as Naunuko Pahiro for 4hr 20 minutes with submergence of Seti khola village.Likewise, many major rivers like Kaligandaki, Karnali, Sunkoshi, Bhotekoshi as well as Tinau, Bagmati, Kamala and Bheri are already been damned by landslides for the long time been (Baral, 2012).

Study Area

Sildujure V.D.C. lies towards North-East (N-E) part of Kaski District of western Development Region. In the Northern boundary there is Parche V.D.C. In the eastern part there is Namarjung and Parche V.D.C. In the western part Armala and Sardikhola V.D.C. and in the southern part it is attached with Mauja and Thumako dada V.D.C.Geographically, it is located 84.02^0 to 84.09^0 east longitude and 28.24^0 to 28.35^0 north latitude with an area of 38.58 Sq.km. The average slope of the study area is about 30^0 to 70^0 (Fig.3).These areas were the part of the Middle mountains.

The study area (Fig.2) basically lies between the Chasu bazar and Seti khola gaun. TheMadi River flows parallel to the study area. The flow of the river from Himalayan to Damauli is altogether 64km. It possesses a drainage area of 858sq.km.Madi river at Sishaghat has latitude of $28^0$06’00’’ and longitude $84^0$14’00’’ with an elevation of 457m. At the study area near Madi river there is characteristics in topography of forming gentle and steep slope, due to geological structure. The gentle slope varies from 30^0 to 35^0 and the steep slope with 50^0 to 70^0 which generally appear alternatively. There is a merger of Chiplikhola and Madi River ahead of the main slide towards North. In the study area there were Seti khola near Seti khola gaun, small gully with flow of water near Pordi and small tributary near Taprang landslide (Fig 2). However, except Madi river and small rivulets there were no other lake and other big rivers. Big scale of landslide is generally observed on the western part of Mad River at Tap rang.

The land use pattern in the study area (Figure 2) is mainly divided into the woodland and the farmland. The wood land of Sildujure V.D.C. is 24,518 ha and farmland is further classified under Danaharakhet of total area 7,622 ha and Pakhobariof6, 201ha. Cultivable land basically consists of clayey silt and sand with gravel mix. Towards north of Sildujure V.D.C.there is a large range of Annapurna Himal ranging from 7000m to 8,000m approximately. (Annapurna-1, 2, 3) So, almost the climatic condition in this V.D.C. is mostly cool. Basically, temperature in this region varies from maximum 33^oc in hot season and minimum of 6^oc in cold climate. Most of the rainfalls almost 90% occur in *Grismaritu* and remaining 10% in *Hiudh.*

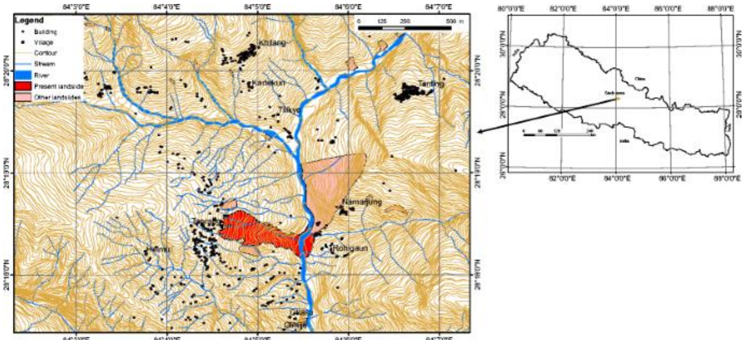

Figure 2: Geological map of Tap rang area including the Taprang landslide
(Source: Regmi et al., 2016)

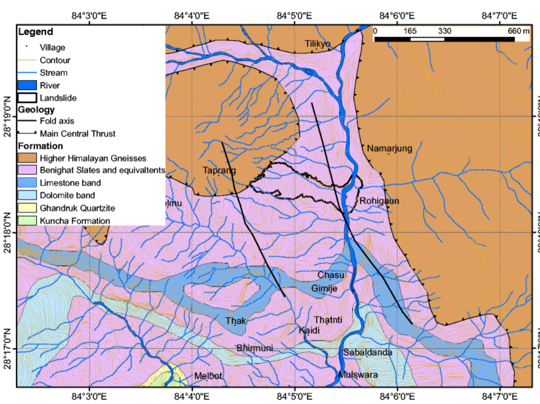

Figure3: Geological map of Taprang area
(Source: Regmi et al., 2016)

Landslide and flood hazard are the devasting and destructive natural disaster phenomena which are being frequently occurred in the middle mountain region of Nepal. Loss of lives and property due to Geological and hydrological events is common in developing countries like Nepal.(Baral Prakash 2012).This study analyse the geological hazard(Landslide) and flood frequency in the middle mountain region of Kaski, Madi River, which include the possibility of re-occurrence of landslide, condition of ground water table, time of concentration, correlation between rainfall and runoff as well as hydraulic conductivity and rainfall, discharge at the outlet of landslide to Madi river, estimation of losses including consumptive use as well as discharge and velocity at Madi river with flood frequency after 25 years, 50 years and 100 years and potential risk for civil engineering structures in it.

This will finally contribute positive impact in future to local people of the Rural Municipality to know the major factors causing hydrological and geological hazard in the middle mountain region. In developing countries like Nepal, it is helpful in adopting risk assessment programme at central, provenance as well as at local level.

Objectives of the Study

The general objectives include Hydrological and Geological analysis of cohesive soil and its potential risk in Middle- Mountain Region of Nepal with reference to a Naunuko Pahiro (Tap rang Landslide) along a Madi River, Kaski ,Nepal.

The Specific objective of the study includes:

1. Determining the correlation between rainfall-runoff as well as hydraulic conductivity and rainfall.
2. Estimation of different water losses in a hydrological cycle.

3. Determining discharge of catchment as well as discharge at outlet of study area (Naunuko Pahiro) along with velocity of flow.
4. Determining the level of ground water table.
5. Determining the flood frequency in middle mountain region with cohesive soil where mountainous river prevail for 25 years, 50 years and 100 years respectively taking consideration for a Naunuko Pahiro and Madi River.
6. Analyse of different soil test value which were achieve as secondary data and determine the factor of safety by altering the different value of "i" and "H" for predicting nature of Geological hazard(unstable, critical and stable) in Middle Mountain region of Nepal.
7. Prediction of the risk for civil engineering structures for 25 years, 20 years and 10 years design period taking arbitrarily in the Middle Mountain region of Nepal.

The study is based on secondary data and information, which is previously collected from field survey and tested in lab by the researcher himself. For the process of analysis statistical and probabilistic approach was used and empirical formulas were applied.

Limitation of the Study

The study is limited to middle mountain region of Nepal with cohesive soil (Silty Clay) lies and often previous landslide occurs. Rainfall data for 10 years were due taken into consideration. Most of the data were collected from secondary data. Hydrological and Geological hazard analysis tool such as GIS, SHALSTAB, deterministic methods are not being utilized. Soil conservation regarding geological hazard and hydrological hazard assessment are not being included in the study. This gives only general idea to concentrate for further investigation in cohesive soils in Middle mountain region of Nepal.

RESEARCH METHODOLOGY

Secondary data have been used previously based on soil sample technique(lab test), various maps, rainfall data for 2000 to 2010, temperature data, statistical technique, probabilistic approach and use of different empirical formulas regarding hydrological aspect the researcher have been able to predict the possibility of re-occurrence of landslide, rainfall-runoff relationship, hydraulic conductivity(K) and rainfall relationship, Factor of safety(F.O.S), groundwater table ,water losses, discharge at outlet of landslide, velocity of flow, flood frequency at Madi river and potential risk for civil engineering structures which prevail there.

The correlation is developed on the basis of Karl Pearson formula as (Sharma, 2015):

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2\Sigma(y-\bar{y})^2}}$$

The Gumbel's equation is basically utilized for determining flood frequency of a river given as: [9]

$Y_T=1.2825(X-\bar{X})/\sigma_X+0.577$……… (1)

$K=(Y_T-0.577)/1.2825$……. (2)

$X_T=\bar{X}+K\sigma_X$……………………. (3)

Where,

X_T=Value of the variate X of a random hydrologic series with a return period T

$\bar{X}$ =mean of the variate

σ_X=Standard deviation

K= frequency factor

Hydrological and geological hazard in the middle mountain region of Nepal are more susceptible to risk for civil engineering structures like bridge, hydropower as well as river training works and various retaining structures. The hydraulic design values are assigned on the basis of risk estimation which is given by the equation as (Subramanya, 1999):

$R=1-\bar{R}=1-(1-1/T)^n$

Where,
$\underline{R}$=Risk
$\overline{T}$=return period
n=Design period

Geological hazard includes landslides which denote" the movement of a mass of rock, debris or earth down a slope under the influence of the gravity" (Cruden, 1991). It is a downslope movement of a soil or rock mass occurring dominantly on surface of rupture or relatively thin zones of intense shear strain. It includes wide range of ground movements such as rock fall, deep failures of slopes and shallow debris flow. Gravity acting on a steepened slope is primary reason of landslide (USG, 2004). Terzaghi defined the landslide as a rapid displacement of a mass of rock, residual soil or sediment adjoining slope in which the centre of gravity of the moving mass advances in a downward and outward direction.

Some of the factors which cause landslides were: rock and soil type, strength, rock structure (folding, faulting, jointing, foliation and bedding), soil depth, porosity, permeability. The secondary causes were seismicity, intensity of precipitation, land use, natural slope conditions, presence or absence of gullies, streams and rivers and groundwater conditions. (Upreti and Dhital 1996).

Rainfall is an important geological (landslide) triggering agent especially in Middle mountain region of Nepal, where 80% of the annual precipitation occurs during the months of June to September. The penetrated water increases the pore water pressure, consequently decreasing the shear resistance which can lead to slope failure. Stream banks were also subjected to erosion and scour by flowing water. The morphology of drainage system adjusts to the moderate and high magnitude floods to which they were regularly subjected in the upper parts of the catchments areas of Nepal. During rainy season the river show most activity in lateral cutting of banks. This process often results in the formation of landslides in the Middle mountain region of Nepal where cohesive soil (Silty Clay) prevails (Dahal et al., 2006).

The relationship or association between two quantitatively measured or continuous variables is called correlation. The extent or degree of relationship between two sets of figures is measured in terms of another parameter called correlation coefficient. It is denoted by 'r'. Karl Pearson's Correlation Coefficient is basically used to measure the degree of linear relationship between two variables. (Sharma Suresh K 2015).The correlation between rainfall and runoff as well as rainfall and hydraulic conductivity helps to better analyse the hydrological and geological study in middle mountain region of Nepal.

The stability of the slope can be analysed on the basis of slope stability equation. This equation, of which there are a number of variables, determines the factor of safety as per the different soil characteristics. The factor of safety (F.O.S) is used in the engineering sense as the ratio by which the shear strength of the slope material exceeds the shear stress in the material. The numerical value of factor of safety 1 means that the slope is at the dividing line between being stable or unstable. If the factor of safety is more than 1, the slope is stable. If it falls below 1 it will be unstable. The advantage of this method is that it is based on the slope stability analysis and allows the calculation of quantitative values of stability i.e. factor of safety. The factor of safety is calculated for different soil conditions and classified according to its numerical value. The formula for calculating Factor of Safety (F.O.S) is given as (Baral, 2012)

$F.O.S.=C+\Upsilon_{sub}H\cos^2 i*\tan Ø/ \Upsilon_{sat}H\cos i*\sin i$ … (1)

Where,
C=Value of cohesion
Υ_{sub}=Submerged density
H=Depth of sliding surface
Ø=Angle of internal friction
Υ_{sat}=Saturated density
i=Slope angle of particular slide

Due to foresight of this technique i.e. if applied to middle mountain region of Nepal which are frequently victimize due to hydrological and geological hazard it is possible to move and evacuate potential victims to area of safety well before they occur and special attention can be given in assigning design period for civil engineering structures. Overall, this gives only the general ideas to concentrate further investigations in the specific area.

RESULTS AND DISCUSSION

Results

Table 1: Hydrological factors and their calculated values at Taprang Landslide Zone.

S. N.	Description(Hydrological Factors)	Calculated value	Remarks
1	Rainfall return periods	12.04 years	-
2	Rainfall at reoccurrence interval of 12.04years	446.50cm	-
3	Rainfall-Runoff correlation	r=1	perfectly positive correlation(r=+1)
4	Correlation between hydraulic conductivity and rainfall	(0<r<1)	moderately positive correlation
5	Value of k for 30min, 15min and 8 minutes	58.4168, 59.4168 and 7.530	-
6	Evaporation loss	167.147	-
7	Transpiration losses	12.6%	Vegetation Cover
8	Interception losses	111.625cm	-
9	Consumptive use	278.898cm	Agricultural land
10	Total water losses	439.059cm	Sum of losses due to evaporation, interception and consumptive use
11	Time of concentration	0.16hour	-
12	Ground water table	1.452m	High
13	Total infiltration rate	12.583cm/hr.	-
14	Total density of snow melt	32.8135	High snow melt
15	Discharge at outlet of middle mountain where slide prevails	770.989m^3/s	-
16	Discharge from Madi River excluding discharge at outlet of the slide	2,174.785m^3/s	-
17	Velocity of flow at landslide zone	0.729m/s	-
18	Flood frequency, 25years,50 years and 100 years	844.096m3/s, 912.258m^3/s, 979.955m^3/s	Goes on increasing with elapse of time
19	Risk for civil engineering structures, 25 years,20 years and 10 years design period	87%, 81%, 56.56%.	Lesser the design period with safety measures is less vulnerable.

Table 2: Geological factors and their calculated values at Taprang Landslide Zone.

S. N.	Description(Geological Factors)	Calculated Values	Remarks
1	Shear stress (τ_f) at 5kg,10kg,15 kg load sample	0.79	Less
2	Normal stress (6_n)	0.277	-
3	Angle of internal friction (Ø)	64.84^0	-
4	Submerged density (Y_{sub})	17.377kn/m2	-
5	Saturated density (Y_{sat})	2.711 kg	-
6	Value of cohesion(C)	0.2	Lesser cohesion value
7	Factor of safety (F.O.S) at different value of i (50^0 to70^0) and H (19.9m, 18m and 10m) respectively.	0.791, 1.142, 0.539	Critical, Unstable, Unstable

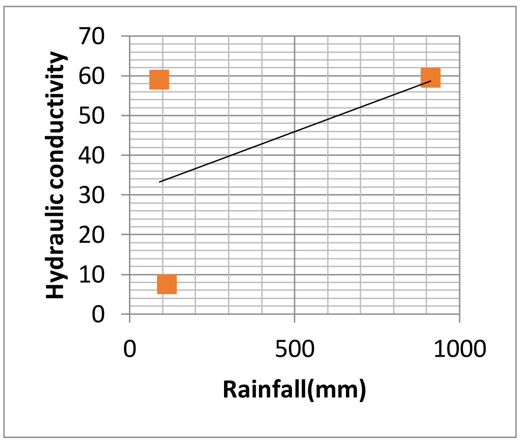

Figure 4a: Hydraulic conductivity and rainfall

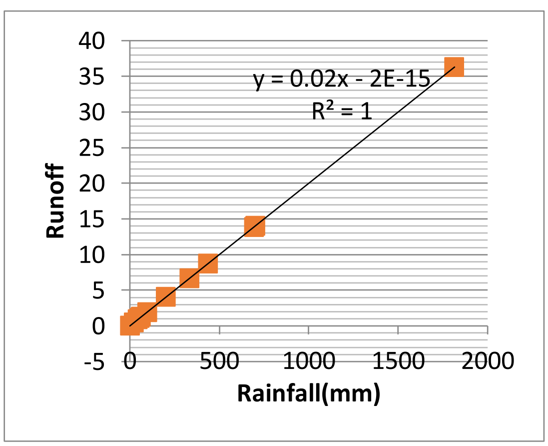

Figure 4b: Runoff and rainfall

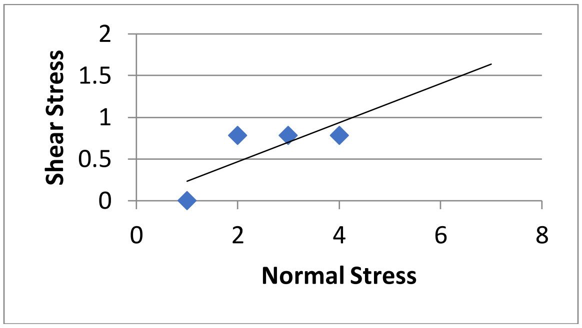

Figure 4c: Shear stress and normal stress

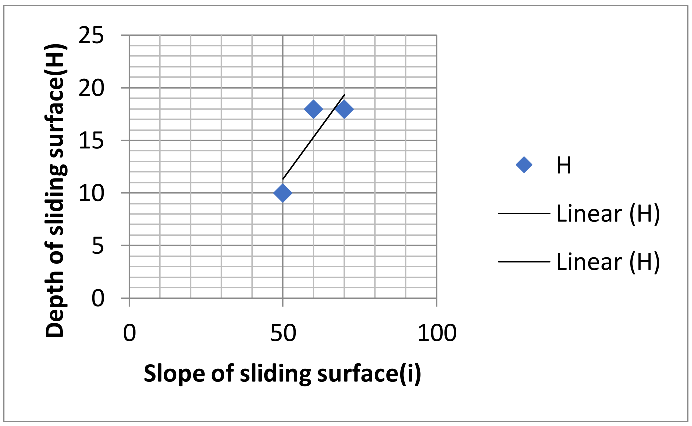

Figure 4d: Depth of sliding surface and slope of sliging surface

DISCUSSION

The rainfall return period of 12.04 years along with re-occurrence of 446.50cm (Table 1) reveals that the runoff tends to increase with higher ground water table and hydraulic conductivity. The total water loss and water infiltration rate pattern shows the higher flood frequency which increases with time from 25 years to 100 years. There seems to be risk for civil engineering structures for greater design period almost 87% for 25 years (Table 1) in such re-occurrence nature of rainfall within a return period of 12.04 years (Table 1) The rainfall return period as increases, the hydraulic conductivity tends to increase. There is lesser value of cohesion 0.2.At different value of ''i" ranging from 50^0 to 70^0 and "H" varying from 19.9m to 10m (Table 2) a value of factor of safety(F.O.S) was calculated. From these calculated values it reveals that slope is critical and unstable (Figure 4a, Figure 4b, Figure 4c, and Figure 4d).

Most of the researcher conduct their study based on modelling using GIS to assess vulnerability for adopting a safety measures regarding different slope failure stability. Rock Mass Rating (RMR) and Slope Mass Rating (SMR) are also used to identify strength of rock quality and soil as well in unstable topography. In this study the researcher tries to study the risk of failure of previous landslide on the basis of simple calculations using different empirical formulas. The correlation were established between different hydrological parameter and soil parameter as per requirement of the study which were found to be almost positive which assist the reliability of the study

CONCLUSIONS AND RECOMMENDATIONS

The study focuses mainly on possibility of re-occurrence of Taprang Landslide, Sildujure V.D.C. Madi Rural Municipality at Kaski, Gandaki Provenance and possibility of flood hazard at Madi River just downstream from landslide. The data analysis helps to know about the area regarding hydrological and geological condition in the Middle mountain region of Nepal. The geological stability of an area at varying 'i' and 'H' are analysed by calculating Factor of Safety (F.O.S).As per theory of infinite slope for a steady seepage flow along a slope implies that value of Factor of Safety<=1, <2 and >1 and >=2 indicates unstable, critical and stable conditions. Different major parameters of soil and water were used during slope stability analysis like value of cohesion(C), saturated dry density (γ_{sat}), slope angle of the slide(i),angle of internal friction(Ø), depth of the sliding surface(H).The study develop a correlation between rainfall and runoff as well as hydraulic conductivity and rainfall. Estimation of different losses including consumptive use was determined using various empirical formulas along with time of concentration (t_c) along the slide area. Discharge through Naunuko Pahiro was calculated on the basis of survey data previously available. Flood frequency estimation for 25 years 50 years and 100 years were estimated using Gumbel's equation at geological hazard zone in the Middle mountain region of Nepal. Risk hazard analysis in Civil Engineering structures for their design period is determined. Results shows that with increase in discharge(Q), flood frequency increases for 25 years, 50 years, and 100 years respectively, which lead to the possibility of flood hazard by overtopping the banks of Madi River. On varying the value of 'i' and 'H' ($50^0$to 70^0) slope tends to be critical and unstable and also since rainfall runoff relation is positive. So, the reliability of this method was increased which has less error.

Likewise, different hydrological and geological analysis explored in the present study can be equally applied in the areas of similar biophysical conditions with cohesive soil in the Middle mountain region of Nepal such as slope of Mahabharata including mountainous rivers prevailing there. Water should be allowed to flow freely to minimize flood hazard without blasting due pond formation at the river course. The houses located at steep slope in similar topography of Middle mountain region should be facilitated in migrating to the safer place. Most of the rainfall in the Middle mountain region contribute to the base flow and ground water rather than surface run-off, with higher discharge at outlet and lesser time of concentration(t_c) leading to hydrological(flood) hazard. Regarding flood the flood frequency tends to increase due to geological instability, climatic variability with elapse of time i.e.25years, 50 years and 100 years respectively. So, preserving vegetation must be taken in consideration, avoiding to overgrazing of cattle in the Middle mountain region of Nepal. The Civil Engineering structures (bridge, retaining structures) basically must be design for short duration with adequate safety measures in such pattern of rainfall. Road construction at the toe of Middle mountain must be constructed with bio-engineering works. The research findings ultimately will be helpful for Department of Soil conservation, DOR (For road alignment), DOI (For canal alignment),Water Induced disaster mitigation, Stakeholders, NGO, INGO,NARMSAP for effective implementation of plan and policies regarding soil conservation and flood hazard assessment in the Middle mountain region of Nepal with cohesive soil (Baral, 2012)

REFERENCES

Baral, P. (2012).Slope stabilization and mitigation measures of Naunuko Pahiro at Sidujure V.D.C., Kaski: Oodbodhan, A Technical Journal, Pashchimanchal Campus, 1(1), 182-190.

Dahal, R.K. (2006). Geology for Technical Students (1st ed.).

Dahal, R. K., Hasegawa, S., Masuda, T., Yamanaka, M. (2006). Roadside slope failures in Nepal during torrential rainfall and their mitigation. Universal Academy Press.Inc./Tokyo,Japan.

Dhittal, M. R., Thapa, P. B., Dahal, R. K., Aryal, A., Ando, H. (2002). Status of landslide hazard in the Kusma-Syagja area of Western Nepal Lesser Himalaya Bulletin, 9.

Gupta, B.L., Gupta, A. (1999).Engineering Hydrology (3rd ed.).

Regmi, A. D., Yoshida, K., Cui, Peng. Hatano, N. (2016). Development of tap rang landslide, West Nepal, Landslides, 14(3).

Sharma, S.K. (2015). Nursing Research & Statistics (2nd ed.)

Shrestha, B. R., Raj, K., and Marasini, S. (2020). Review of flood hazards studies in Nepal. The Geographic Base, 7, 24.

Subramanya, K. (1999). Engineering Hydrology (2nd ed.).