Preliminary study of landslide risk evaluation by micro landform interpretation on southern slope of Siwalik Hills, Nepal, using aerial photo interpretation
—A case study of Shrawan danda landslide Butwal, Rupandehi, Nepal—

Bishnu Prasad GYAWALI and Toyohiko MIYAGI

Abstract

Landslide induced disaster is a serious problem in the mountainous terrain of Nepal. The landslides and debris flows cause losses of lives and properties, damage the nature and other infrastructures in the monsoon every year. The risk evaluation of landslides is to be most important for landslide hazard reduction. This paper is to focus on evaluating the potential landslide topography of Shrawan danda landslide which lies on the southern slopes of the Siwalik Hills and has created serious problems in Butwal, Nepal. The series of the investigation methods have been carried out to identify the characteristic of each factor of the micro landform of the landslide through interpretation of aerial photographs incorporated with the information of field survey and historical records. The maps and related tables were converted to digital format from the database that was the part of the geographical information system (GIS). The information of aerial photo interpretation has been used for risk evaluation of the landslide based on the AHP method.

Firstly, Shrawan danda landslide was divided into three landslide bodies (A, B and C) based on the geomorphological features of the landslide area. Secondly, the distribution maps of the micro landform features were prepared by using GIS. Thridly, the length, area and density of the micro landform features (scarps, blocks, bare lands and cracks) of the landslide bodies were calculated. After that, the detailed information of instability of the landform features of the landslide bodies were analyzed for risk evaluation. Finally the weight of risk value of the micro landform features produced by the AHP method were used for classifying the landslide bodies as one with high, moderate or low risk.

The results show the weight of risk value of the landslide body A = 44, B = 90.4, and C = 76.4 points. The weight of risk value of the landslide body B and C were found more than 70%. These landslide bodies are highly contributed by the number, length and density of the micro landform features which are perceived as high risk. The weight of risk value of the landslide body A was found between 30 to 70% which is moderately controlled by the number, length, area and density of the micro landform features that is perceived as moderate risk. Thus results of qualitative and quantitative estimation of the micro-landform features led by using GIS and numerical function, and the weight of the risk value of the micro landform features led by using Analytical Hierarchy Process (AHP) method synthesizing information of the aerial photo interpretation (API) provide a precise contribution to evaluate risk of a landslide in various environmental conditions.

Key words: micro landform feature, aerial photo interpretation, GIS, risk evaluation, AHP

1. Introduction

Landslides in mountainous regions have caused major problems such as losses of lives and properties and damage to the nature and other infrastructures in many places in the world. The contribution of human activities and natural factors combined are the main causes of the landslide trigger. Risk evaluation of potential landform of landslides has become more important for hazard reduction and for saving lives and properties. The landforms of Nepal are characterized as fragile geology having major thrusts, faults and folds, steep slopes, narrow gorge river and valleys. Several types of mass movements are recognized in the mountains and hills for examples: rock falls, rock slides, rock creeps, avalanches in the High mountain and rock falls, creeps, soil creep, slip slides, deep slumps and gullies are common in the Mahabharata (Middle Mountain) ranges and Siwalik Hills (Lower Mountain) (Sharma, 1981). Furthermore, rapid growth of the setting population and the landform encroachment on hill slopes for example: deforestation, agricultural used in steep slopes, irrigation channel and road construction in the Middle Mountains and Hills have created more pressures on marginally stable lands (Tamura, 1996; Chalise, 2001; Upreti, 2001, ). In addition, several triggering factors such as heavy rainfall, earthquake, high intensity of weathering combined with human activities have influenced the mountains to be highly vulnerable to landslides and other mass wasting processes in the mountainous regions. The landslides, debris flows and floods have caused a huge loss of materials and given a impact directly and immediately to the people, properties and infrastructures in every monsoon.

The southernmost hills of the Himalaya from 200 to 1000m asl ranges are called Siwalik Hills (Churiya hills). Geomorphologically the landforms of the Siwalik Hills

* corresponding author

a) JSPS Postdoctoral Research Fellow in Tohoku Gakuin University
b) Tohoku Gakuin University
1-3-1, Tsuchitoi, Aoba-ku, Sendai, 980-8511, Japan

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are fragile, highly rugged terrain and dissected by numerous gullies and landslides (Upreti, 2001) that have created serious hazardous problems at the southern foothill and plain. Shrawan danda landslide existed on the southern slope of Siwalik Hill composed of young sedimentary rocks (sandstone, shale, mudstone and conglomerate) of the Lower Siwalik Formation which overlies on the crusted loose colluvial of the Quaternary deposit, which lies just behind the Main Frontal Thrust (MFT) (Tokuoka, Takayasu, Yashida and Histrati, 1986; Sharma, 1990; Gautam, and Appel, 1994) has created serious problems to Butwal Town (Jyotinagar and Laxminagar), Nepal (Fig. 1). The Shrawan danda landslide is most important in connection with human the settlements in Butwal (Jyotinagar and Laxminagar) which is business town growing rapidly having the population of about 80,000 is located at the foot hills and both sides of Tinau River.

Shrawan danda landslide occurred on 12 August 1998 after a high intense rainfall (DPTC, 2000). The unstable masses were reactivated on 29 August and 5 September 1998 and one person was killed, five people were injured in a debris flow at the foothills. The property of estimated amount about NRs. 58 millions was damaged by the huge amount of the debris flow of the landslide in Jyotinagar and Laxminagar (Gyawali, 2003; DPTC, 2000). This landslide is still in active where more than 10,000 people are living in the vulnerable area migrated from the mountains and hills. They are also not very familiar to the real condition of landslides triggered by the process and the potential area of landslides and becoming victims by landslides and debris flows during heavy rainfalls. The hazard assessment and risk evaluation of the critical micro-landform features of Shrawan danda landslide are becoming more essential for protection of properties and saving people from disasters. This paper has focused on firstly a technique to identify the micro landform features of the landslide through the aerial photo interpretation (API) and prepared the maps using GIS (Arc view 3.2a). Secondly, the number, length, area and density of the micro landform features have been calculated and finally the information gained by API has been used for risk evaluation of landslide bodies based on analytical hierarchy process (AHP) method. The finding results support prioritizing potential area in the landslide, land-use planning, developing infrastructures and a reliable prediction of potential losses of lives and properties.

2. Methods

2.1 Landform classification and landslide process

The changes of geomorphic process of landform due to deep-seatd landslides in the mountainous terrain are characterized by the instability and variability of the surface slope. Much of the instability of the hillslope surfaces is the result of sliding as well as various causes of landslide development processes. Mass movements depend on the geological structural, geomorphological features and the material types (Vernes, 1978, 1998; Miyagi, 1979; Yagi, 1996). The processes of landform changes in landslide area can be identified...
by interpretation of micro-landform features such as scarp, crack, bare land slope, block separation and debris flow deposit, pressure ridge and depression in the landslide body by using API. The sequences of landslide movement from unstable (active) stage to stable (inactive) stage are highly controlled by the degree of freshness, shape and size of the micro landform features (Fig. 2). These micro-landform features of the landslide body reveal the degree of a potential stage of the landslide that can be judged through interpretation of aerial photographs of a given period of time (Miyagi and Konno, 2003).

2.2 Risk evaluation hypothesis by the viewpoint of landslide and topography developments

Landslide risk appraisal involves acquiring the knowledge of hazard assessment for ranking qualitatively, and quantitatively information of the micro-landform features. The hazard assessment is defined by the characters of landforms, triggering factors, size, type, movement, location and approximate coverage area of mass movement as well as material properties. The post-failure behaviour of failing masses of a landslide is very difficult to predict because sufficient information to understand the processes of landslide does not exist. The development of micro landform features of a deep seated landslide is controlled by geological and hydrological influences. The development of these combined and interrelated processes may cause a landslide to occur. Thus an analysis of micro landform features enables us to find out potential landforms of landslides and predict the degree of risk because the potential hazard and high vulnerability lead high risk. Furthermore, available references of geological, hydrological information and past historical records also reveal more precise and effective judgment for risk evaluation of a landslide.

An AHP based risk evaluation hypothesis based on aerial photo interpretation was contributed by the project (Iwate Prefecture and Japan Landslide Society 2003). The authors applied the methodology to the target landslide. The model chart of micro-landform features of the landslide was developed for risk evaluation by discussion among landslide experienced scientists (Fig. 3) based on Analytical Hierarchy Process (AHP) method (Saaty TL, 1980). The model chart of micro-landform features was tested by interpretation micro-landform features of 150 different landslides on the mountains of sedimentary rock in Iwate Prefectures, northeast Japan through the aerial photographs. The standard Analytical Hierarchy Process (AHP) method
was applied for risk evaluation. This report to identify AHP score of micro-landform feature of landslide has been referred to a paramilitary study of landslide risk evaluation of micro-landform of the landslide on the southern slope of Siwalik Hills Nepal.

First of all, the risk evaluation of the micro landform features of the landslide were classified into three major types: (1) micro-landform feature of landslide body, (2) Major boundaries of landslide topography, (3) landslide body and adjacent environment (geomorphic setting). In the second step, the micro-landform feature of the landslide body was sub-classified into four: A to D, and major boundaries of the landslide topography was classified into three: E to G, and the landslide body and adjacent geomorphic environment were classified into two; H and I as shown in Fig. 3. These items sub-categorized from A to I were classified into details, and the weight of risk value varying from instability to stability stage of the micro-landform feature were marked. The total marks of risk value have given 100 points that distributed to each micro-landform features of the landslide based on the degree of danger (Fig. 4).

The result suggested that the weight value of risk varies from 0 (no landslide risk) to 100 (high landslide risk) in the potential hazard zones. Furthermore the weight value was categories as follows: risk value $>70\% =$...
Fig. 5 Shrawan danda landslide (1996), the long solid arrows show the old landslide scarp and small arrows show the linear cracks on the deformed hill slopes above the old landslide

Fig. 6 Shrawan danda landslide after event of 12 August 1998, (The big white and red arrows show the main scarps of old and recent landslide and small white arrow shows the some cracks.)
Geomorphologic features of landslide area (Fig. 7). The moving masses and debris flow of landslide have disturbed the hill slope topography, drainage patterns and gentle slopes and flat lands at the foot of Siwalik Hills. The gentle slopes and flat lands filled with the dense public and private residences of Butwal town (Jyotinagar and Laxminagar) has been found partly buried and partly disturbed by debris flow deposition of landslides.

The major active scarp created in the middle section of the main scarp by recent landslides occurred has abruptly dissected and separated the landslide bodies from the lower ridge of original hill slopes of Siwalik Hills. The slope angle of the major active scarp have been found varied from 38 to 40° and slope lengths varied from 5 to 30m. Several numbers of minor active scarp and is the bare land area were recognized on the landslide bodies after sliding mass of recent landslide events (Fig. 8, 9). Several deformed blocks which observed on the landslide bodies have been controlled by several linear ground cracks (Fig. 10, 11). Fractured bedrock was observed on the exposed scarps and bare land slopes of the landslide bodies. The blocks in the upper and lower section of the bare land slope of the landslide body have partly moved and partly been in an unstable condition. The debris flow on the bare land surface runs through the channel and made debris fans, small gullies and talus at lower portion of landslide bodies A, B and C. These landslide bodies have been interrelated separately with the flows.

The shape of the main scarp in the crown section of the landslide body-A has observed as stable and smooth steep cliff that has been modified moderately by eroding process because small gullies with imma-
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Fig. 11 Distribution of crack features on the body of Shrawan danda landslide on the southern slope of Siwalik Hills Butwal Nepal

Fig. 12 Left side photograph shows the over view of Shrawan danda landslide and right side photograph shows a view of old landslide scarps in the upper section and recent landslide scarps in the lower section of the slope on the landslide body B

Fig. 13 Landform features of old landslide body of Shrawan danda landslide on the southern slope of Siwalik Hills Butwal Nepal (This landform features were interpreted by aerial photographs which was taken in 1996)

ture vegetation covered the body and tree crown deformation are clearly visible there. The landslide body consists of concavely smooth slopes and covered with thin forest. No distinct block has been observed but a few numbers of cracks have been marked as the tree crown deformation on the surface of the landslide body. The 4 minor active scarps of minimum 84m and maximum 472m in length were observed in the lower section of the landslide body. These scarps and bare land were developed by collapse and sliding movement of the lower unstable blocks due to downcutting of the stream. The exposed bedrock of the bare land slopes are highly weathered, jointed and contained fractured of sandstone, mudstone and conglomerates. The cracks short in length with irregular shapes were observed on the gully heads.

The major active scarp which observed in the head section of the landslide body B was reactivated by collapsing unstable crown of the old landslide on 29 August 1998. The major scarp appeared as a semi-circular type was found fresh, steep and extending from east to west. The exposed bedrock is found highly weathered and contained fractured of sandstone and mudstone (Fig. 12). The 13 minor active scarps from 37m to 561m in length were developed in irregular forms in middle sections of the landslide body. 10 piece of bare land with a sliding surface observed in the upper, middle and lower sections of the landslide body are deep and widely expanded. The huge amount of debris flow have made two big fans more than 80m wide 100m long and several small fans at the foot hills. The 8 blocks on old landslides body which were found through interpretation of 1996's aerial photographs (Fig. 13) were partially deformed and controlled by several cracks; these blocks have been well deformed and separated into more than 24 blocks by the events of recent landslides occurred. Among these, a big block on the head of landslide body B has been found highly deformed at present. The cracks on the head block are in its advanced stage having about 1m deep and 50 cm wide and have extended in irregular forms. The head block has been dissected by these cracks and tilting back, toward the main scarp. The front part has subsided forward (Fig. 14A) and partly moved by toppling and falling and partly been in an unstable condition. The huge number of broken boulders has been observed in an unstable condition at the foot of the scarp. The sleep surface of the head block was estimated 50m deep which seems to be pushing the lower section of the landslide body because a hummocky type of topography with some small depression and
Fig. 14 The photograph A shows the linear cracks on block head of landslide body B and photograph B shows the linear crack on the middle section of landslide body B

Pressure ridges, haphazardly tilting trees have been noticed in the middle section of the landslide body. The cracks scattered in irregular forms were also found in the middle section of the landslide body that have made voids at several places (Fig. 14B). Active gullies which have been developed at the lower sections are also extending upward at the head of landslide.

The main scarp of landslide body C has been found as a steep and concave type as shown by the solid line. Four minor scarps with new surface slide were observed from 72m to 200m long on the head of the landslide body. The bare land with sliding surface is sallow type, the debris flow has not much affected the lower section. A huge block observed on the head of the landslide body which has partly disturbed by the cracks are in an unstable condition but has not moved yet. Most of the cracks of the landslide body are open types, short in length, developed in irregular forms and concentrated in the middle section of the landslide body. Small taluses developed at the foot of scarp are moderately covered with immature bush vegetation. The gully heads at lower slope are highly controlled by linear cracks appeared to be highly potential to be reactivated (Fig. 11).

4. Quantitative estimation of micro landform features of Shrawan danda landslide

The data of micro landform features which have been generated by maps through the use of GIS tools were used to calculate the number, length, area, and density of cracks, scarps, bare land and blocks of the landslide bodies (A, B, C).

The minor active scarps were found 21% on landslide body A, and 10% on landslide body C. The scarps density was estimated as 2,044m/km² on landslide body A and 2,400m/km² on landslide body C (Fig. 15). The area of landslide body B has been affected by 69% of total scarps. The total scarp density was found on landslide body B = 5,500m/km². These active minor scarps which have been developed by the recent landslide and distributed on the head, in the middle as well as in the lower section of the landslide body have highly affected the landform of the landslide body B. The bare land area on the landslide body A and C was found 3% of each body and the density of the bare lands was found on the landslide Body A = 0.0084 km²/km², C = 0.019 km²/km² and on landslide body B = 0.28 km²/km² (Fig 16). Thus the recent mass movement has affected the whole area of the landslide body B and few areas of the head section of landslide body C and lower section of landslide body A.

The total length of the cracks measured on each of the landslide body: B = 54%, C = 30% and A = 10%. The crack density measured on each of the landslide body: A = 300m/km², B = 900m/km² and C = 1500m/km² (Fig. 17). The area covered active with deformed blocks found on each of the landslide body: A = 0%, B = 88% and landslide body C = 12%. The block density found on each of the landslide body: B = 0.33 km²/km² and C = 0.13 km²/km² (Fig. 18). Thus the results suggest that the landslide bodies B and C were found
more highly active and highly controlled by scarp, block separation as well as by numerous cracks formation than the landslide body A.

5. Risk evaluation of Shrawan danda landslide using AHP

The information of micro-landform features obtained through the aerial photo interpretation has been used for risk evaluation referring to the AHP method by the interpretation sheets (Fig. 3, 4). The topography boundary of the landslide body-A is clearly visible. The minor scarp on the head of the landslide body has been modified moderately by erosion process and small gullies have developed, and they are covered with immature trees at present. The scarp is not active but the surface which exposed its bedrock partly is deformed in the upper section due to a highly weathered condition. The body of the landslide consists of smooth and clear micro-landform. The unclear blocks deformed on the landslide body and development of gullies indicates that the last movement of the landslide occurred several years ago and the erosion process was continued. The surface topography of the landslide body in the middle section is also covered with vegetation. The linear cracks on the landslide body which were recognized based on tree crown de-

formation. The condition of slope changes abruptly from a steep one to gentle one in the middle section. The boundaries of the landslide body and the front are smooth surface. The landslide body in the middle consists of slopes of which conditions partly vary changing slopes. The slope angle at lower section of the landslide body is 35 to 40° and deep gullies eroding upward are to be at progressing order. The unstable mass has been broken and has slid down losing support due to scouring and downcutting by the stream flow. The total weight of risk value of the overall micro landform features of the landslide body marked 44 points on the landslide body A.

The flow mound and pressure ridges observed on the landslide body B are deformed by linear tension cracks and steep fresh scarp. The landslide body B is controlled by a huge number of deformed blocks, and micro topographic boundary was found very clear. The huge number of deformed blocks and clear micro topography has made the landform have an unstable condition on the landslide body. The exposed bedrock is highly weathered at the top and lower ridge of the landslide body. The head block tilting backward, toward the major scarp and the depression has been developed toward the foot of major scarp. Irregular open cracks having 0.5 to 1m deep dissected the lower part of the head block. The active minor scarp in the lower section of the head block is an echelon type. The head block is moving rotationally. The landslide body B observed as non talus consisted of highly deformed landslide blocks and the surface of which condition abruptly varies develops the minor scarps. Several cracks in irregular forms have been observed on the landslide body. The blocks in the middle section of the landslide body are a hummocky type depending on a part and have thick deformed masses, some blocks with big boulders and broken rocks are in an unstable stage. Several bare land surfaces, unstable deformed hill slopes with depression, tilting trees, and irregular cracks have been developed in the middle section as well as active gullies have been developed in the lower section of the landslide body. Thus the total weight of risk value of the micro landform of the landslide body marked 90.4 points on the landslide body B.

A clear main scarp was observed at the top ridge of the landslide body-C that has been developed by moving unstable slopes. A mount and pressure ridge have been observed on the landslide body. The minor active scarp has been developed on the unstable mass of the old scarp as well as in the landslide body. The land-
form condition in the middle section of the landslide body C is a shallow types and debris deposited with unclear deformed blocks in the middle section, but the block on the head of the landslide body C has partly been deformed and dissected. Dense open cracks extending at irregular directions concentrated in the middle part of been the landside body. The minor scarp is an echelon type. Scarp talus and landslide body were found in lower slope section. Small gullies were developed at the lower section and no distinguished flow channel was found at the down stream.

Under the geomorphic environment of adjacent area of the landslide, the front body is a convex type and steep at the lower section developed along with small gullies and formed flat land at the foot hills that have already been occupied by the people's residences. The irregular cracks in the lower section indicate the landslide body has increasing order which is considered to be a high risk. Thus evaluating risk value of such several critical micro landform features of the landslide body C marked 76.4 points. Thus the total weight of risk value of the landslide bodies evaluated by using AHP methods found as follows.

Landslide body A = 44 which between 30 to 70% of the total weight of risk value = Moderate risk

Landslide Body B = 90.4 which is >70% of the total weight of the risk value = High Risk

Landslide Body C = 76.4 which is >70% of the total weight of the risk value = High Risk

6. Result and discussion

The result of risk values of the micro landform features evaluated by AHP method, and the estimated values of density, number, length and area in percentage of the micro landforms features (cracks, scarps, bare lands and blocks) have been discussed for categorizing risk of the potential landform of the landslide body (A, B and C).

The detailed distribution map of the micro landform features of Shrawan danda landslide pointed out the quantities and source area of the landform features through the use of GIS (Fig. 19). The degree of freshness, shape and size of the micro landform features of the landslide vary from an unstable (active) to a stable (inactive) stage. The old to fresh scarps and bare land distribution of the landslide body indicate the actual frequency of the accuracy of a landslide, and the shape length, and size of the cracks and block separation suggest the stage of instability of the landslide body. If a smaller number of cracks with shorter in length covered the landslide area that would suggest that the potential area has considered to be shallow and the have smaller risk while the long and deep cracks suggest the movement of mass landslide is deep and its large

Fig. 19 Detailed distribution of micro-landform features of Shrawan danda landslide on the southern slopes of Siwalik Hills, Butwal Nepal
coverage area is considered to have a high risk, and the blocks suggests the actual coverage area of the landslide body.

First description shows the qualitative features of the landslide. Shrawan danda landslide is found tightly related to the geology and tectonics characteristics of the source area which has been reflected on the micro landform features of the landslide. The main scarp of the lower ridge of the Siwalik Hills is found stable and covered with vegetation in the head section of landslide body A, the active and fresh in head section of landslide body B and the shallow slope failures and active gullies with moderately covered with vegetation in the head section of landslide body C. This type of clear boundary of the landform of a landslide suggests that the evolution of Shrawan danda landslide has come through several stages since the ancient time till now. The very first landslide was caused by the accumulation of highly weathered, jointed and fractured sandstones shale/mudstone on the steep slope. The highly fractured bedrock of the Siwalik Hills was developed by crushed of tectonic moment because the Siwalik Hill, which lies just behind the Frontal Churia Thrust (FCT), has been affected by the tectonic movements (Sharma, 1990). The development of linear cracks on the crown of the Shrawan danda landslide was caused by crushed moment of the Siwalik Hills that causes the potential hill slope to have a landslide still at present.

The upper section of the landslide body A has been modified moderately by the erosion process and covered with immature trees at present, but partly exposed bedrock with highly weathered, smooth slope in the middle scansion and the lower section affected by deep gullies eroding upward suggests the landslide slide body A has at moderate risk. The head block of the landslide body B tilting back with depression formed behind the block being partly dissected by cracks indicates that the head block is moving rotationally and it is possible that the front section is to be moved by falling and toppling. The middle section of the landslide body B is partly a hummocky type having thick deformed masses with a huge amount of deposited big boulders in an unstable stage. Thus whole mass of the landslide body with big boulders being in an unstable stage ca move down by toppling, rolling and bouncing and sliding until the energy dissipated at any time and this mean that this landslide has been considered to have high risk. The landform condition in the middle section of the landslide body C is a shallow type but dense open cracks extending irregular, small gullies at the lower section, indistinct flow channel at the down stream and flat land at the foot hills. Thus the unstable deformed land surfaces suggests that the middle section of the landslide body C has a high possibility to have sliding processes, thus the landslide body is considered to have high risk.

The result of estimated values of numbers and length in percentages of the cracks and scarps of the micro landform as shown in Fig. 20 have been found more than 50% on the landslide body B, between 10 and 30% on landslide body C and A. The affected area of the bare lands have been found >10% on the landslide body A and C and more than 50% on the landslide body B. The block separations were found more than 50% on the landslide B and between 10 and 20% on the landslide body C. The density of the cracks was found below 1km/km² on the landslide body B and A, and more than 1km/km² on the landslide body C. The density of the scarps was found less than 2km on the landslide body A and C and more than 5km/km² on the landslide body B. Similarly the density blocks were 0.28km²/km² on the landslide body B and below of 0.1 km²/km² on the landslide body C. The mean value of the density of the micro landform features (cracks, scarp bare land and blocks) have been found 12% on the landslide body A, 52% on the landslide body B and 36% on the landslide body C.

The selected factors of instability (number, length and coverage area in percentage and density) of the micro landforms are more or less take to bring about given instability processes of the landslide depending on the actual and accurate processes of investigation and using the tools for analyzing the generated data. Thus the comparison of the results obtained by AHP Methods and Quantitative value obtained by calculation of the generated information obtained by the GIS tools found out more similar significant ratio of categorizing the risk value of the landslide bodies. The weight risk value measured by using AHP showed the well defined micro landform features however it did mention neither the quantity nor impact by potential landform of the landslide nor the frequency of the factors of the micro landforms features clearly.

7. Conclusion

We would like to conclude the investigation of instability of the micro landform features of Shrawan danda landslide that the Shrawan danda landslide is an old and complex type reactivated recently by the unstable
blocks of the old landslides and partly deformed the original slopes of Siwalik Hill which have been controlled by several linear cracks and deformed blocks. The result of risk evaluation of landslide, which was divided into three landslide bodies (A, B and C) based on the landslide topographic features and the density of scarp, block separation, bare land slope of sliding mass and cracks distribution measured shows that the landslide body B is highly vulnerable and has high risk, the landslide body C has moderate risk and the risk landslide body A has comparatively is lower than these landslide body B and C have.

The result of weight value of the micro landform features, which was evaluated by AHP method for categorizing the landslide according to the level of the risk they have show that the landslide body A = 44, B = 90.4 and C = 76.4 points. Thus weight of risk value of the landslide body B and C found < 70% are perceived as high risk which are highly contributed by density of the cracks, scarp, block separation and bare land slopes. The weight of risk value of the landslide body-A found between 30 to 70% was perceived as moderate risk. Such combined results of the micro landform features, and its weight value of risk by AHP methods suggests that landslide body B and C which showed the high risk evaluation are vulnerable and possess serious threat to the residential settlement of Jyotinagar and Laxminagar where more than 10,000 people are living and other important infrastructures are laying. This is the preliminary study of qualitative and quantitative measures of micro landform features by using GIS and AHP methods for the risk evaluation of the landslide body synthesizing the information of aerial photo interoperation. This type of study provides the quick result of risk value of potential landslide which can be used prioritization of potential landform of a landslide for a reminding people of awareness of risk of a landslide and construct infrastructures avoiding the risk. These methods have been applied for the single deep seated landslide and the results has been found more significant however the information may not be sufficient to be applied for several types of landslides, therefore the study on several other landslides are required to improve the value incorporating into more parameters for more accurate risk of landslide.

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