GIS-Based Terrain Analysis of Balakot Region after Occurred Landslide Disaster in October 2005

ABDUL SALAM SOOMRO*, ABDUL QADEER KHAN RAJPUT**, AND ISMAIL RAKIP KARAS***

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ABSTRACT

The landslide susceptibility models require the appropriate and reliable terrain analytical based study of the landslides prone areas using SRTM (Shuttle Radar Topography Mission) data, based on certain GIS (Geographical Information Systems) and remote sensing techniques. This research paper focuses on the analysis of the terrain conditions of Balakot region. The analytical operations have been used in the different phases: (i) Extracting the study area from the large data; (ii) preparing it into grid format; (iii) developing contour lines with certain contour intervals (iv) Re-classification of it into required classes and (v) preparation of digital terrain model with its different required various supplementary models for analyzing the terrain conditions of the study area located in Mansehra district, north part of Pakistan where the great earthquake induced landslide disaster occurred in October 2005. This analytical study has notified the different sensitive issues concerning to the critical slope angles, variation in the elevation and the surface of study area. The various distinctions in the terrain phenomenon validate the occurred and probable landslides because the topography of such study area can predict the various probable landslide hazards, vulnerability and risk threats in the region again. This analytical study can be useful for the decisive authorities by becoming pro-active to rebuild the region to mitigate the expected losses from the natural disaster.

Key Words: **Landslide Susceptibility, Terrain Analysis, SRTM Data, Supplementary Models, GIS, Remote Sensing.**

1. INTRODUCTION

Landslides being failure of block slides from the steep to low lands is counted as great disaster which occurs in the terrain mountainous circumstance and has always remained the topic of interest for the various school of thoughts to lessen their hazard and the risk proactively [1]. Landslides being great local and global concern in the world of the geo-environmental sciences have the various fissuring trends in the diverse geophysical circumstances [2]. Slope failures being indication of the fissuring of the topographic phenomenon originated from the obtained satellite data [3]. It has been noticed that many triggering of the landslides have been

* Ph.D. Student, Department of Industrial Engineering & Management, Mehran University of Engineering & Technology, Jamshoro.
** Professor, Department of Computer Systems Engineering, Mehran University of Engineering & Technology, Jamshoro.
*** Assistant Professor, Department of Computer Engineering, Karabuk University, Karabuk Turkey.

happened in the similar topographic conditions [4]. The rail fall are counted as the triggering cause of the fissuring of the slopes is mostly considered in the humid environmental possessing terrain hills [5]. The hot weather liquefies the glaciers on the mountains and become the cause of the slope failures by creating pore water in the internal structure of the material of the rocks and make them shallower to be fallen [6].

The topography of the rocks becomes damaged because of the inherent properties of mountains, and the hard climate especially in the tropical areas where every time, there is the storm of rainfalls which weaken the bare mountains especially [7]. The development of the landslide hazard, risk and the susceptibility models need the proper and critical examination of the various forms of slope, general tendency of the topography before and after landslide disaster applying the elevation data of shuttle radar topography mission utilizing the different approaches nd operations of geographical information systems nd remote sensing.

The landslide hazards haven considered by concerning its falling tendency, run out and the evolution by years wise in the change of the terrain situations [8]. The susceptibility of the slope failures have been suggested to focuses on the spatial extent and location of its fall [9] which helps in the development of the landslide susceptibility model using any of the approach and any of the category of the slope failures in this regard. The most utilization of GIS has been remained to develop the various features of the topographic modeling using topographic analysis [10]. The various potential data themes such as elevation, slope angle, digital surface model, and contours with the various extents of intervals using the different type of the SRTM data are utilized using GIS for the topographic analysis.

2. BALAKOT STUDY AREA

The terrible earthquake induced landslide disaster occurred on 8th October 2005 in Balakot in the northern territory of Pakistan with remarkable scale [11] caused the thousands of fatalities and millions of the dollars and the properties [12]. Balakot is tropical area covered with high steep mountains and dense forests. The earthquake threat remains every time to this area beause of the fault lines lying in the mid of this area [13]. Balakot city posses the two most famous valleys of world named as Kaghan and Naran. The peak of the mountains in this area is 4000-5000m asl (above sea level). Balakot study area has been shown in Fig. 1.

The GIS methodology for topographic analysis has been drawn as shown in Fig. 2.

The flow chart methodology ahs been explained by deviating it into two sections; first to extract the small required study area data from the huge data and second to analyze it for terrain conditions using some of the techniques of Geographical information systems and digital image processing. The topographical analysis was done applying the two different GIS and Remote Sensing software. First all required small size of data concerning to the interest area of region as Balakot was clipped from the large stock of data as Pakistan boundary. After extracting the required data from the huge data the different techniques were applied on the shuttle radar topographic data to convert it into grid format making eligible as raster format for developing the different contour lines with the approximately above 95 m intervals. The raster data as grid data was applied for making the tri-irregular net work model into required regions depending on the interest. After that the various classified data from TIN (Terrian Model) was reclassified into five classes. After that the different other auxiliary required models such s slope, aspect, hill shade, profile curvature and digital surface model were prepared.

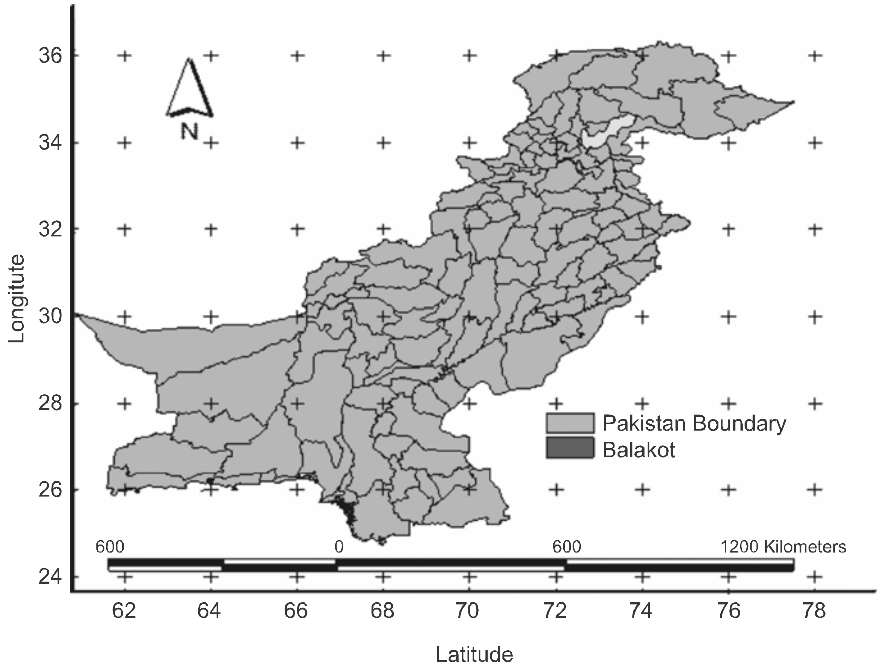

FIG.1. MAP OF BALAKOT

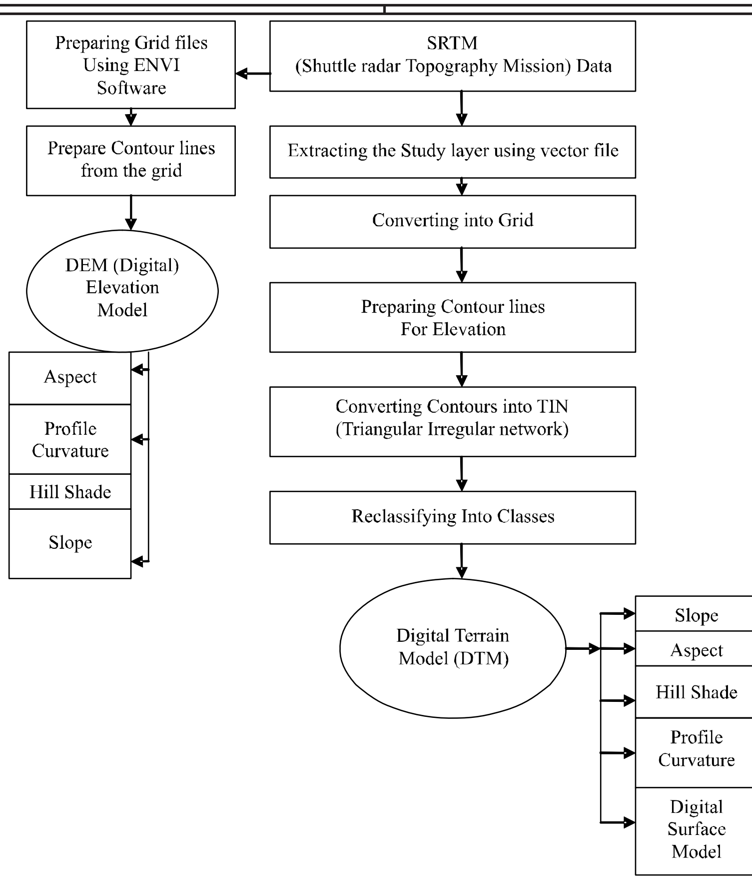

FIG. 2. METHODOLOGY FOR TERRAIN ANALYSIS

3.1 Extracting the Study Area from Huge Data

The huge data derived freely with courtesy of GLCF (Gloval Land Cover Facility) , ESDI (Earth Science Data Interface), with path 150, row 36, using WRS (World Reference System) II with 90m spatial resolution as shown in Fig. 3 was utilized to clip for the required region to analyze the topography of it.

The area of interest's interest called as study area was extracted as shown in Fig. 4 utilizing its latitude (N) 34.3300, 34.5500 and longitude (E) is 73.2100 and 73.3500. the data characteristics are; projection as UTM (Universal Transverse Mercator) , zone 43 North , Spheroid as (world geodetic system) WGS 84 with Path 150 and Row 36, using (WRS) II belonging to the study area were matched in the grid data using the vector data by verifying it into the similar projection and the datum of the data.

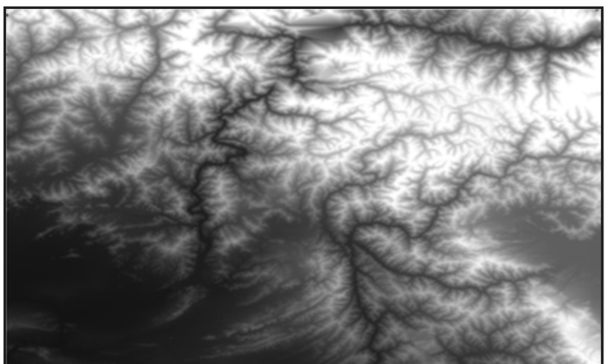

FIG. 3. SHUTTLE RADAR MISSION TOPOGRAPHIC DATA [14]

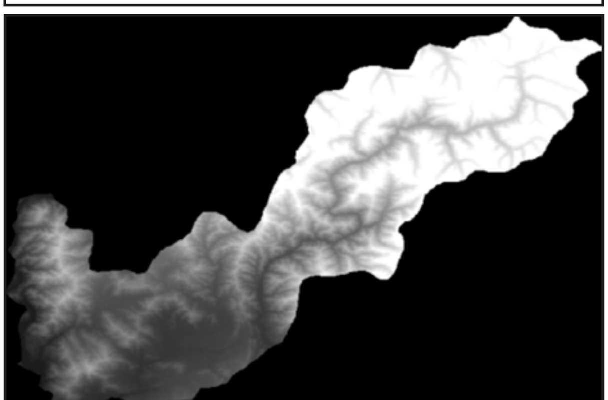

FIG. 4. BALAKOT STUDY AREA CLIPPED FROM HUGE DATA

4. RESULTS

4.1 Digital Terrain Model

The digital terrain model was found out with various categories of elevations and the surface terrains as shown in Fig. 5. The five categories of elevations has been presented as ; The first category of the terrain conditions belong to the range of elevation from 0-988.8 meter asl. This category of the topography concerns with the natural low land of the area where the flow water discharge from the steep of the mountains and accumulates there making shallow ere the mountains by the pore water pressure.

Normally the experts of geomorphology call the low land as alluvial plain land where the water fall from the different catchments areas and it is the pure natural slope form where the triggering and the fissuring occur in that inclination from the steep of the mountains. The second level of the topographic terrain conditions ranges from 988.8-1977.6m which is along the road and the river lines in the study area. This terrain situation is considered as very dangerous being eroded y the mountains due to the proximity of road and stream. The third category of the terrain condition is ranging from 1977.6-2966.4 meter asl which covers the elevation along the river and the

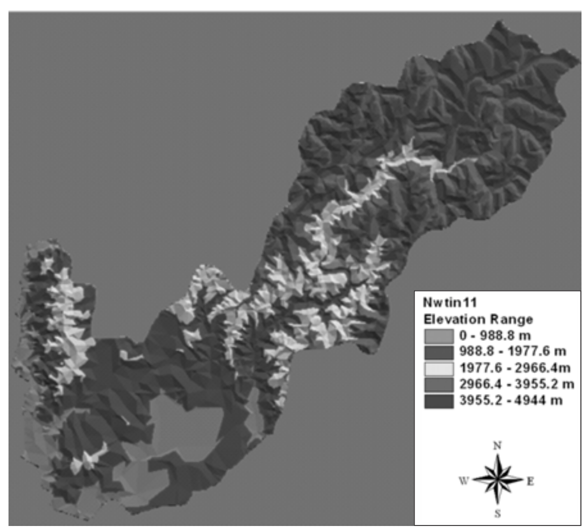

FIG. 5. BALAKOT TERRIAN MODEL

catechumen areas from te west direct mostly. The fourth category of the elevation ranges the second topmost steep area covering the elevation range from 2966.4-3955.2 meter asl which is totally covered with the deep catchments areas from where the water falls to the plain land. The very high and the topmost mountains range from the elevation of 3955.2-4944 meter asl which is called as steep mountains with steep crest.

4.2 Digital Slope Model

The digital slope model was achieved as shown in Fig. 6 after getting digital terrain model. In fact this model is auxiliary model using the derived contour lines of the terrain model. The contour intervals were set with 100m because of the nature of the huge data as the SRTM data has 90m resolution which is considered as suitable because of the extent of the study area.

The slope model has been developed representing the different four categories with the different angles. The first level of the slope angle is from 0-15 degree which comprises on the low and the plain land and is known as gentle to gentler slopes. This slope angle is actually safe from its triggering but infact, being the low land; it proves as center of the accumulation of the triggering, flow discharge of the catchments and the occurred landslides from the steep to low land. The second category of the slope angle with 15-25 degree belongs to the catchments areas, second level of low land and covers the topography of the river and the stream lines in the study area. This slope angle has been remained as the landslide prone angle because the various triggering in 2005 has been remained in this type of the angle in this area. The third level of the slope angle comprising with 25-35 degree; possesses the catchments area and proximity to stream etc. The utmost steep areas are with the slope angle possessing the 35.89.75 degree which can re-fall and retrigger the stable type of landslides making them eroded and steep due to the lack of the greenery and the strong burden by using human induces activities such as roads making and building construction etc.

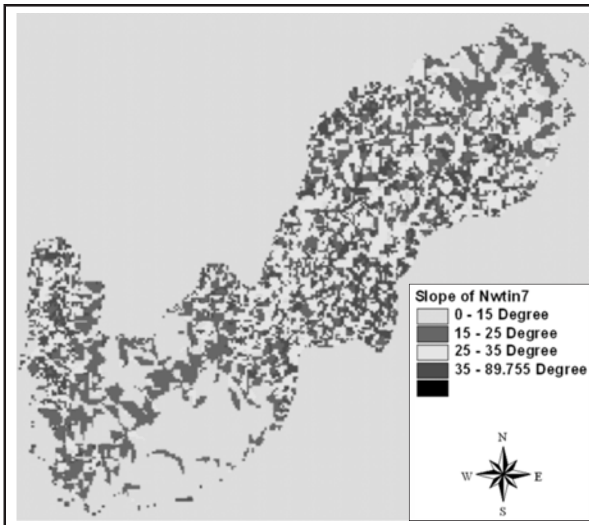

FIG. 6. BALAKOT SLOPE MODEL

4.3 Digital Aspect Model

The digital Aspect Model as shown in Fig. 7 has also been used utilizing digital aspect model. As this type of model helps to view the different angles and the faces of the slope. So that it can be guessed that the terrain fluctuations and topographic phenomenon to understand specially the hazard and risk in the area due to the certain probable landslides.

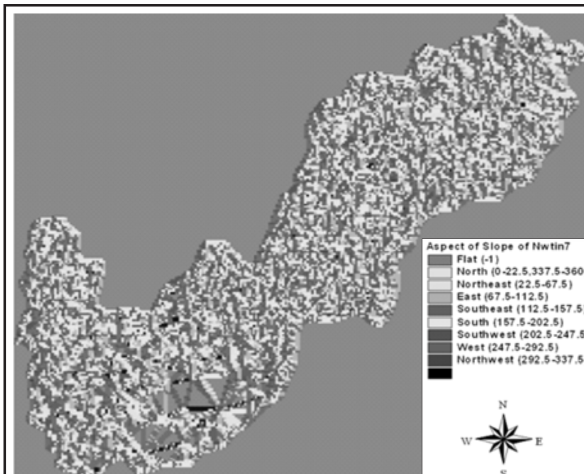

FIG. 7. BALAKOT ASPECT MODEL

4.4 Digital Hill Shade Model

The digital hill shade model is utilized to understand the different places and the variations in the mountains which can guess the sensitivity of the slope form to predict the hazard, risk and the vulnerability with respect to the landslides triggering Fig. 8.

4.5 Digital Profile Curvature Model

This model as shown in Fig. 9 is is benficial to identify the internal maecahnism of the rocky areas. In this model, the various faults lines are examined, which can help to predict the seisimicity of the occuring ccuring landslides.

4.5 The Digital Surface Model

The DSM (Digital Surface Model) as shown in Fig. 10 has been developed using the different remote sensing and GIS techniques.

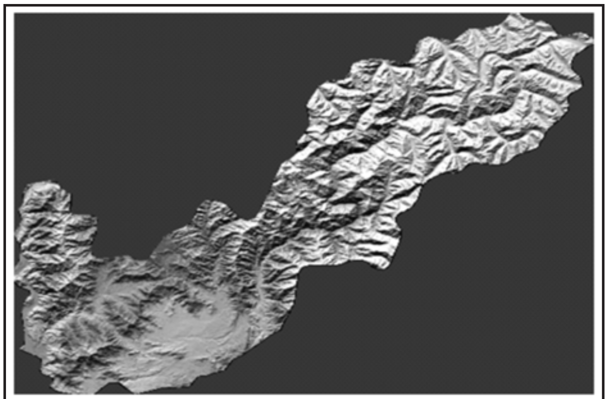

FIG. 8. BALAKOT DIGITAL HILL SHADE MODEL

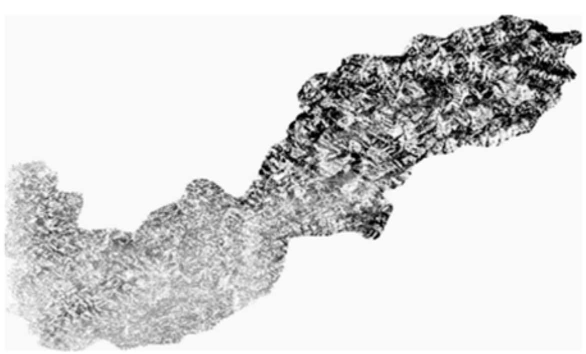

FIG. 9. BALAKOT PROFILE CURVATURE MODEL

In this model one can observe the various dimensions, topographic fluctuations, different levels of elevations, flow of catchments, stream and the river line. This model can be utilized as the validation in terms of the predicted landslide hazard, risk and vulnerability models.

5. DISCUSSIONS

The terrain analysis of the study area is utilized to study the various aspects of the topography and the terrain phenomenon; which can be beneficial for developing landslide hazard, risk and the vulnerability model. This study helps to choose certain probable significant indictors for the development of landslide risk model and also it can be utilize4d for assigning the weight to the different parameters.

6. CONCLUSIONS

The different models such as DEM (Digital Elevation Model), DSM and DTM (Digital Terrain Model) are utilized for understanding the various levels of the elevations and the topography. The best data source for these models is

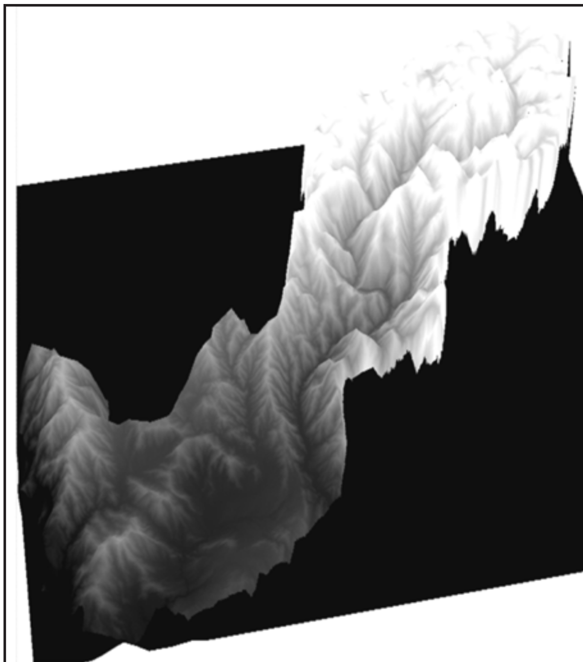

FIG. 10. BALAKOT DIGITAL SURFACE MODEL

SRTM data with 30 or 90m spatial resolution archived by DoD (Department of Defense), USA. The 90m spatial resolution data is also suitable for the medium or large areas but in the case of the catchments or the river basin scale and the analysis for the local scale study area with the 30m spatial resolution data is reliable to predict the terrain fluctuations and the landslide risk models. The appropriate data with certain required resolution helps to develop the accurate and the reliable slope, aspect and the profile curvature models using appropriate contour lines and contour intervals. The suitable data, best usage, suitable techniques and the well known skilled experts provide the best developed predicted hazard, risk and the vulnerability models which can assist the decisive authorities for developing the region in future and becoming proactive in advance to mitigate the losses.

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REFERENCES

[1] Soomro, A.S., Rajput, A.Q.K., and Solangi, S.H., "GIS-Based Fast Moving Landslide Risk Analysis Model Using Qualitative Approach: A Case Study of Balakot, Pakistan", Mehran University Research Journal of Engineering & Technology, Volume 30, No. 2, Jamshoro, Pakistan, April, 2011.

[2] Soomro, A.S., "Landslide Risk Analysis Modeling Using Digital Image Processing and Geographical Information Systems Techniques in Balakot, Pakistan", Ph.D. Thesis, Department of Industrial Engineering & Management, Mehran University of Engineering & Technology, Jamshoro, Pakistan, 2011

[3] Fell, R., Jordi, C., Christophe, B., Leonardo, C.,Eric, L., and Savage, W.Z., "Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land-Use Planning", Engineering Geology, Volume 102, pp. 99-111, 2008.

[4] Van, W.C.J., Van, A.T.W.J., and Soeters, R., "Landslide Hazard and Risk Zonation-Why is it Still so Difficult?", Journal Bulletin of Engineering Geology and the Environment, Volume 65, No .2, pp. 167-184, Springer Berlin/Heidelberg, Germany, 2006.

[5] Khattak, G.A., Owen, L.A., Kamp, U., and Harp, E.L., "Evolution of Earthquake-Triggered Landslides in the Kashmir Himalaya, Northern Pakistan", Geomorphology, Volume 115, pp. 102-108, Elsevier Publishers, Germany, 2010.

[6] Geertsema, M., Clague, J.J., Schwab, J.W., and Evans, S.G., "An Overview of Recent Large Catastrophic Landslides in Northern British Columbia, Canada", Engineering Geology, Volume 83, pp. 120-143, 2006.

[7] Acharya, G., De Smedt, F., and Long, N.T., "Assessing Landslide Hazard in GIS: A Case Study from Rasuwa, Nepal", Bulletin of Engineering Geology and the Environment, Volume 65, pp. 99-107, Springer Berlin/Heidelberg, Germany, 2006.

[8] Dai, F.C., and Lee, C.F., "Landslide Characteristics and Slope Instability Modeling Using IS, Lantau Island, Hong Kong", Geomorphology, Volume 42, pp. 213-228, Elsevier Publishers, Germany, 2002.

[9] Aleotti, P., and Chowdhury, R., "Landslide Hazard Assessment: Summary Review and New Perspectives", Bulletin of Engineering Geology and the Environment, Volume 58, pp. 21-44, Springer Berlin/Heidelberg, Germany, 1999.

[10] Zomer, R., Ustin, S., and Ives, J., "Using Satellite Remote Sensing for DEM Extraction in Complex Mountainous Terrain: Landscape Analysis of the Makalu Barun National Park of Eastern Nepal", International Journal of Remote Sensing, Volume 23, No. 1, pp. 125-143, 2002.

[11] Kamp, U., Growley, B.J., Khattak, G.A., and Owen, L.A., "GIS-Based Landslide Susceptibility Mapping for the 2005 Kashmir Earthquake Region", Geomorphology, Volume 101, pp. 631-642, Elsevier Publishers, Germany, 2008.

[12] Kumar, D.R., Shuichi, H., Atsuko, N.,Minoru, Y., Takuro, M., and Katsuhiro, N., "GIS-Based Weights-of-Evidence Modeling of Rainfall-Induced Landslides in Small Catchments for Landslide", Journal Environmental Geology, Volume 54, No. 2, pp. 311-324, 2008.

[13] Zaré, M., Karimi-Paridari, S., and Mona, L., "An Investigation on Balakot, Muzaffarabad (Pakistan) Earthquake, 8 October 2005, Mw 7.6; Geological Aspects and Intensity Distribution", Journal of Seismol, Volume 13, pp. 327-337, Springer Publishers, Germany, 2009.

[14] Global Land Cover Facility, Earth Science Data Interface, WRS II, (Path 150, Row 36), website:http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp