Landslide Hazard-Prevention in Balakot Region, Pakistan

ABDUL SALAM SOOMRO*, ABDUL QADEER KHAN RAJPUT, AND SARFRAZ HUSSAIN SOLANGI*****

RECEIVED 19.12.2011 ACCEPTED ON 15.03.2012

ABSTRACT

The earthquake triggered enormous landslides on 8th October 2005 in the various areas of Pakistan especially in Balakot Region. This research paper fulfilled the urge to develop alternative landslide planning based on the consideration of landslide preventing measures using GIS (Geographical Informaton Systems) techniques. This specific type of land use planning differs from traditional type of land use planning due to consideration of the probable hazard of landslide disaster by applying zonation methodology for finding the appropriate suitable areas for various development purposes. The various parameters e.g. elevation, slope angle, forest/ vegetations, faults, landslide zones, and rainfall were utilized as GIS data themes in the vector format. The different GIS techniques were used: (i) Clipping the data layers; (ii) Spatial analysis by converting the vector layers into raster format; (iii) Classification of data themes into certain classes; (iv) Overlaying the data themes and (v) Map calculation techniques through GIS standard software. This applied research has found that various different regions such as high suitable, moderate suitable, low suitable and unsuitable may be considered as preventive measures from the probable hazard of the landslide disaster in future for rehabilitation and redevelopment purpose which can save human lives, residential and commercial infrastructure in future. It is believed that the various predicted regions for preventing landslide hazards can be very beneficial to the decision makers for the redevelopment of the region in future.

Key Words: **Land Use Model, Suitability Analysis, GIS Operations, Traditional Land Use Planning, Map Calculation.**

1. INTRODUCTION

The landslides hazards are probable occurrence of the devastations of the human populations, physical materials and the residential and the commercial matters [1]. It has been guided by various experts [2] that the indicating factors and the temporal occurrence of the slope failures should be considered in the geological and the geographical perspective. In this regard, various approaches for the slope fissuring should be considered as the potential way for the effective study of the topography of the rocky areas which remain always fragile in the various tropical and the sub-tropical situations [3]. The knowhow of the effective parameters which develop the dangerous fissuring must be understood [4]. In this scenario, the landslide hazard zonation was preferred using variety of indicators in connection of GIS though map algebra method, by assigning different weights to

* Assistant Professor, Department of Industrial Engineering and Management, Mehran University of Engineering & Technology, Jamshoro.
** Professor, Department of Computer Systems Engineering, Mehran University of Engineering & Technology, Jamshoro.
*** Professor, Center for Pure and Applied Geology, University of Sindh Jamshoro.

the indicators based on the certain criteria, expert's opinions and the field visit [5]. Some of the researchers discouraged it due to the unavailability of GIS data, various technical methods and appropriate skillful people [6]. Furthermore the data conversion is also cumbersome to buy certain required GIS data [7]. However it is a challenging task to develop such type of landslide hazard zonation based planning model based on the reliable criteria and GIS methods.

This applied and fruitful landslide hazard preventing based land use planning is benefited to the different school of thoughts which implement their ideas practically on the large or the small scale either in private or public sectors [8]. The landslide hazard methods are analyzed either qualitatively or quantitatively at any scale as regional scale is preferred for the small and medium areas while local scale is suggested for the simple single type of failures [9]. This type of modeling needs the amalgamation of different areas such as geomorphology, statistical operation based analysis, mathematical approaches including geographical information systems techniques so as to obtain the expected reliable and the better results in that regard. The various approaches has been utilized for developing landslide hazard planning such as Heuristic, probabilistic approach, Statistical, and Deterministic [10]. It has also been suggested to practice on the Heuristic method to generate the landslide hazard zonation based land use planning using specific and causative factors which trigger the fissuring considering the topographic features of the area [11].

The aim of this research paper is to develop Landslide hazard-Preventing Land use planning model using Geographical Information Systems techniques in Balakot region in Pakistan where there was occurred the landslide induced disaster which devastated the whole Balakot region in October 2005. The traditional land use planning models never consider the natural disasters' aspect to mitigate in advance so it needed to develop such type of new land use planning model which may suggest and consider the landslide disaster hazard in advance. This achieved model can be beneficial to the decision makers to develop the region in accordance the prevention of the incoming landslide disasters to save the human lives, residential and the commercial infrastructure to develop the landslide risk models in future.

2. MATERIALS AND METHOD

2.1 Balakot Case Study in Geological Perspective

Balakot region, as sub-division of Mansehra district, in the north territory of Pakistan as shown in Fig. 1, ruined by the terrible earthquake with 7.6 Richer scale on 8th October 20005 induced landslide disaster as shown in Fig. 2, is geologically surrounded with Hazara-Kashmir Syntaxis depicting the edge of MBT (Main Boundary Thrust) [12]. It is covered with high mountains where the main river crosses from its center known as Kunhar River.

Balakot, surrounded by the Indo-Australian plate taken by the northern direction under the Eurasian covering the entire Indian ocean plate, is in the organic belt of Himalaya between the fold and the thrust regions between these described plates [13] as shown in Fig. 3. It was noted that greater part of the triggered landslides were fast moving type of landslides as shallow and the risk fall while the other types of the landslide such as slow moving type e.g. debris falls were at the medium level and the debris flows were at the very low level around 1% [14] .

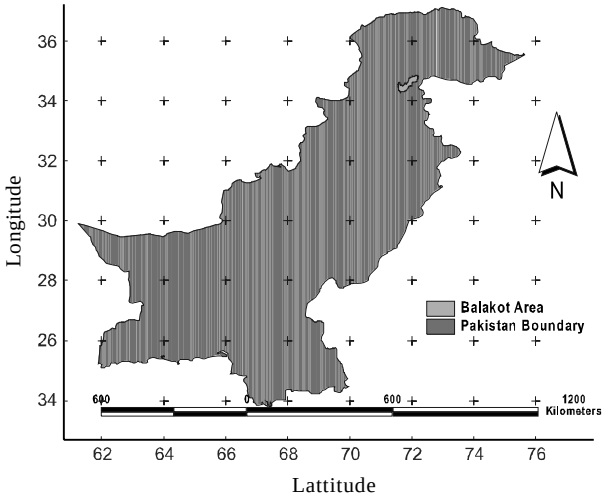

FIG. 1. PAKSITAN MAP

2.2 GIS data Used

The overall parameters/factors of landslide hazard-preventing land use planning model as different data layers in GIS for developing this model areas; DEM (Digital Elevation Model), slope angle, forest/vegetations, faults, landslide zones, rainfall etc. have been incorporated in the GIS software to achieve the required outcome of this research.

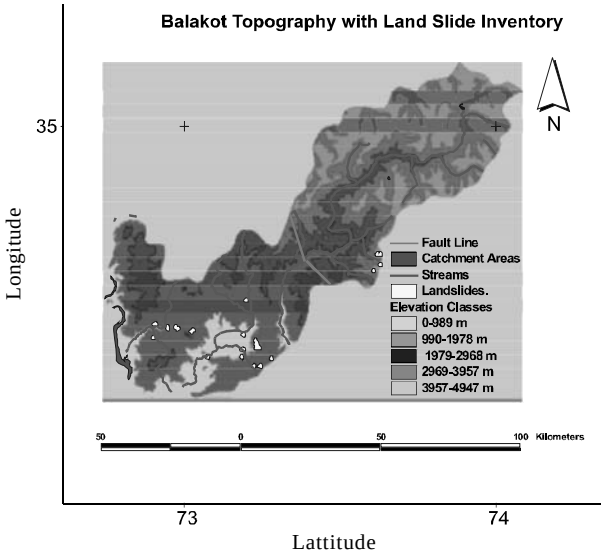

FIG. 2. BALAKOT, STUDY AREA

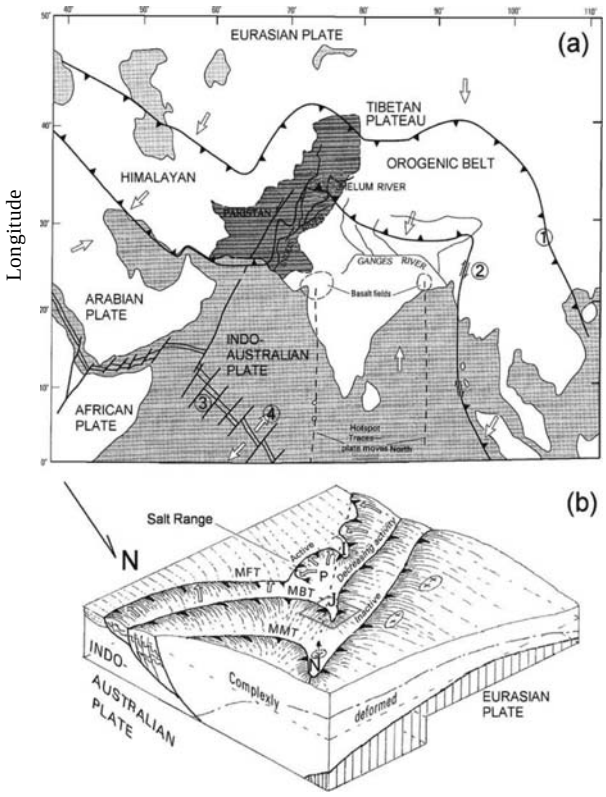

FIG. 3. GEOLOGICAL VIEW OF CASE STUDY AFTER MODIFICATION [13]

2.3 Research Methodology

The flow chart research methodology as shown in Fig. 4 consists of the following different small steps as:

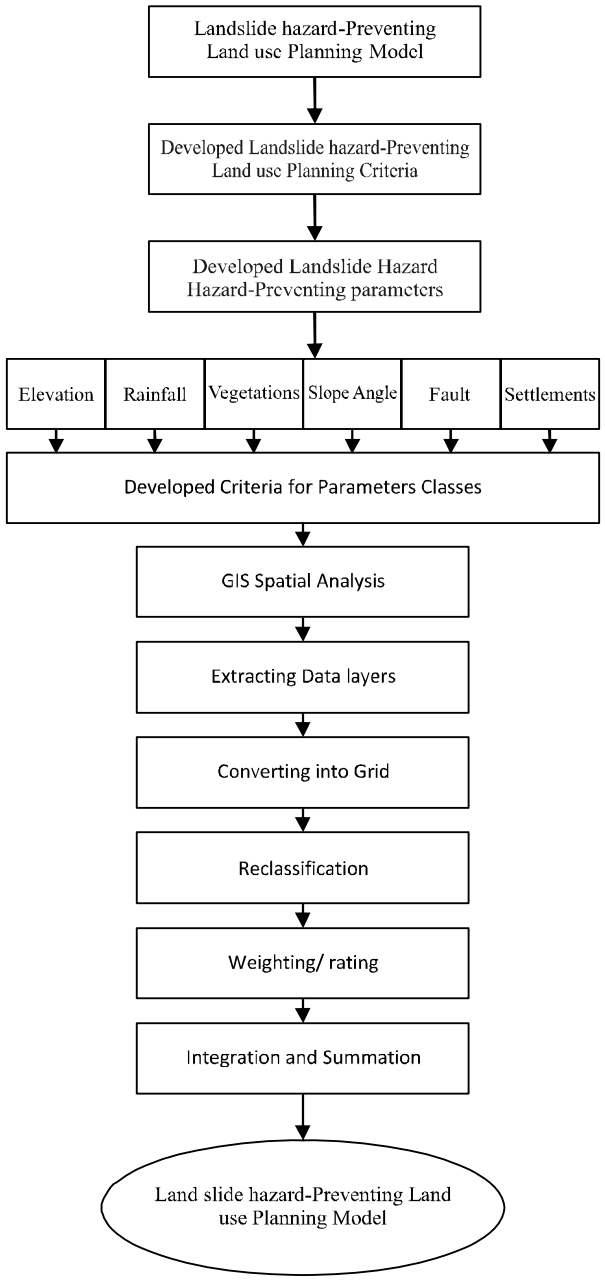

FIG. 4. RESEARCH METHODOLOGY FOR LANDSLIDE HAZARD PREVENTING

First of all this methodology consists of landslide hazard-preventing based land use planning model criteria developed in the four classes as described in Table 1, which suggest to sort out the required parameters weight and importance for developing the model.

After that, the one of the famous technique of GIS as spatial analysis has been used. Through the use of that technique, the different sub-technique such as extracting the GIS data themes was incorporated in which the required GIS themes were extracted from the large data themes of the case study.

The next was using grid converting technique to reclassify the layers into grid format for using spatial analysis technique required settled classes. This model has bane obtained by using the one of the prominent method as 'overlaying the parameters' has been used. Then the map algebra method through the map calculation by adding and the overall factors and dividing them with the total number of the factors in the GIS software with datum WGS- 84, UTM projection, zone 43, was used to obtain landslide hazard preventing land use planning model as shown in Fig. 5. The different data layers have been used in the GIS as shown in Figs. 6-14.

3. RESULT

The result of the research has been achieved as shown in Fig. 15. entitled as the landslide hazard resistant land use planning Model. The four classes such as high suitable, moderate suitable, low suitable and the no suitable have been prepared. Furthermore the definition of suitability classes for landslide hazard resistant land use zoning has been described in that the high suitable class is recommended for construction the homes as it has not any probable risk of future landslides fissuring as the

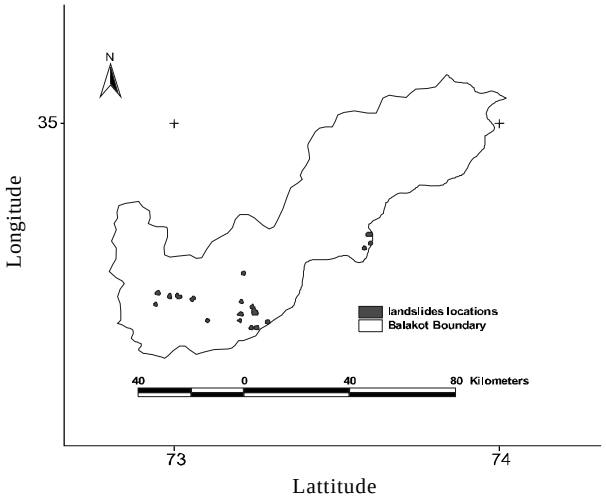

FIG. 5. OCCURRED LANDSLIDES

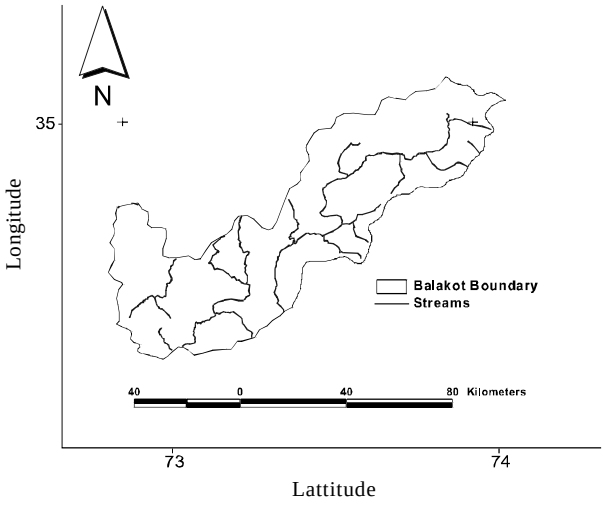

FIG. 6. STREAM NETWORK

TABLE 1. LANDSLIDE HAZARD PREVENTING LAND USE PLANNING MODEL CRITERIA

Parameters	Not Suitable	Low Suitable	Moderate Suitable	High Suitable
Slope Angle	>30°	20-30°	10-20°	5-10°
Elevation	0-1500m	1500-2000m	2000-3000m	3000-4500m
Forest/Vegetations	No Density	Very Less Density	Moderate Density	High Density
Faults	0-500m	500-1000m	1000-1500m	1500-2000m
Landslide Zones	0-500m	500-1000m	1000-1500m	1500-2000m
Rainfall	5000.mm>	3000-5000mm	1000-3000mm	500-1000mm

elevation ranges from peak to moderate hills in the 3000m and above this range. Furthermore, the moderate suitable class belongs to such areas which are near the river sides and are recommended for the tourism and the shopping centers. The elevation of this class comprises to 1500-2000m asl (above sea level). The low suitable classes vary from 3000m to 4000m in the elevation and are recommended for the tourism. The not suitable classes vary from 0-1500m (asl) in the elevation so those classes are suggested not to build any type of construction such as homes, offices, shops, recreational buildings just can be approved suitable for the scouting and the adventurist exercises for the adventurist.

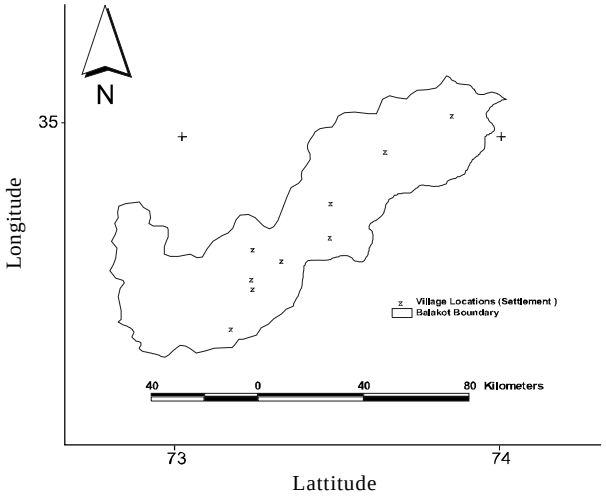

FIG. 7. VILLAGE LOCATIONS

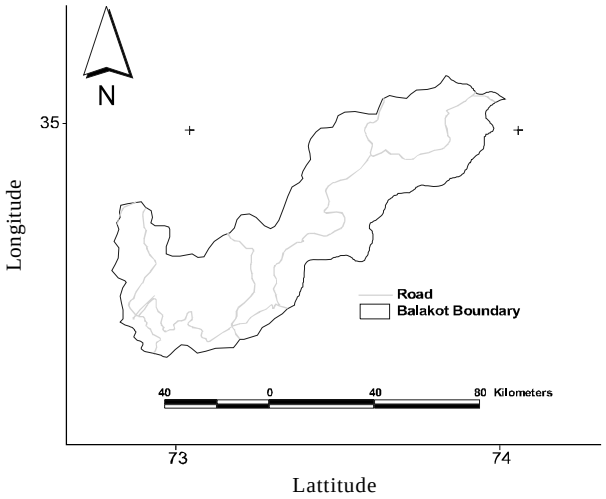

FIG. 8. ROAD NETWORK

4. DISCUSSIONS

The specific type of the landslide risk algorithm based developed landslide hazard, vulnerability and the risk models become supporting to the decisive authorities in terms of the accurate, reliable and the consistent predictions which help them to redevelop the regions in this perspective. This school of thought in this type of the research saves the financial and the technical problems by focusing on the specific type of the landslide risk categories and the models.

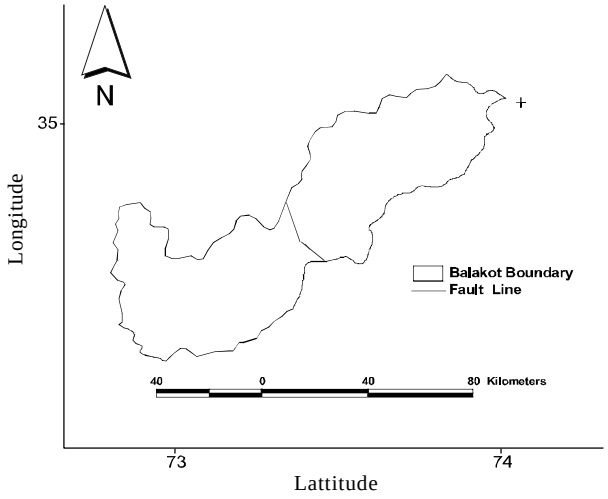

FIG. 9. FAULT LINE

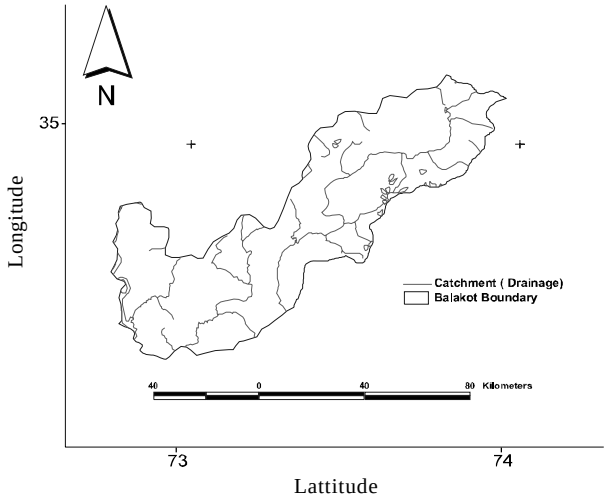

FIG. 10. CATCHMENTS LAYER

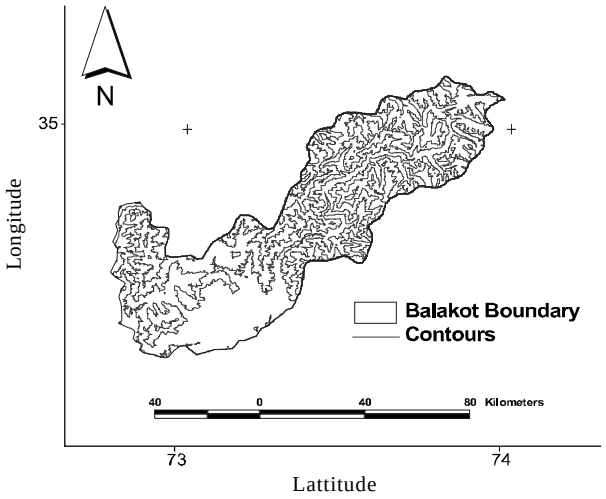

FIG. 11. CONTOURS LAYER

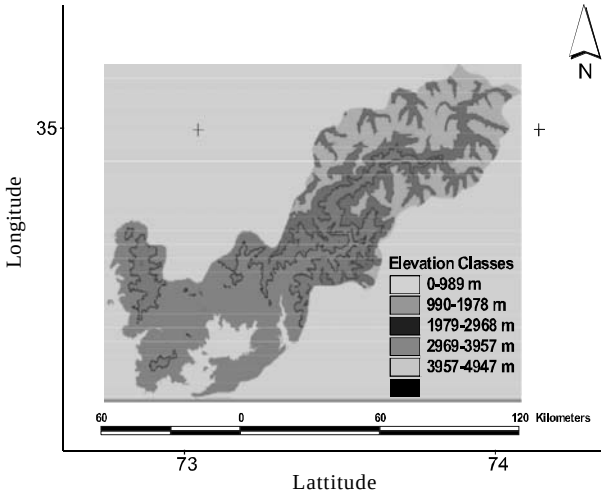

FIG. 12. ELEVATIONS LAYER

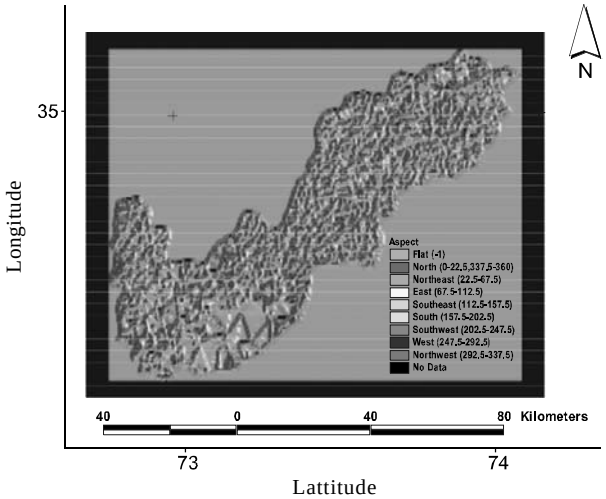

FIG. 13. BALAKOT GIS ASPECT LAYER

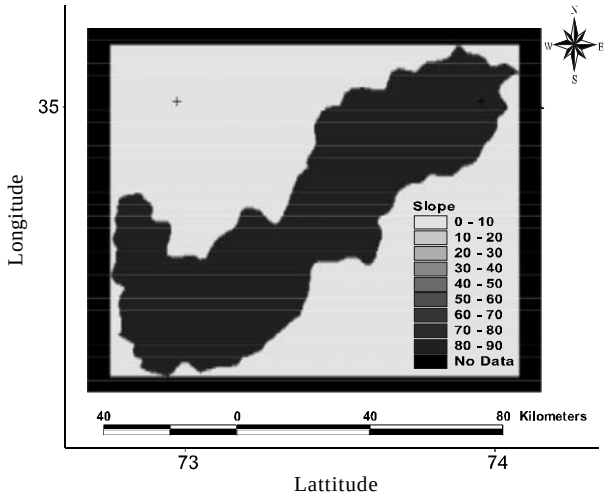

FIG. 14. BALAKOT GIS SLOPE LAYER

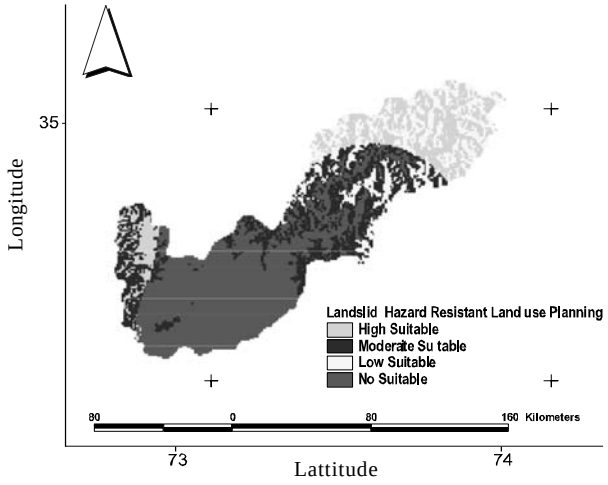

FIG. 15. LANDSIDE HAZARD-PREVENTING MODEL

4. CONCLUSIONS

This research as development of the landslide hazard-prevention based land use planning model using GIS for Balakot region sorted out the suitable areas preventing from the probable landslide hazards e.g. Babusar Parse, Jalakhad Nala etc which can be developed and rehabilitated for the residential and the official purposes, while the medium suitable areas e.g. Lalasar can be used for the tourism, shopping centers but less appreciated for the residential purposes. More over in this research it was found that the inappropriate and not suitable areas which are very hazardous in terms of occurrence of future

earthquake based landslides triggering such as Balakot city, Ghari Habibullah, Oghi, Sri Paya, Shogran, Kawai, Kaghan, Paras, Phagal, Siaf-ul- Malook Lake, Sharan, Kunar River, Lalazar, Malka Parbat, Naran, Moosa Ka Musiala which can be suggested to utilize for the tourism and the adventurism purposes e.g. scouting, army purposes etc.

ACKNOWLEGEMENTS

This written research paper is the part of the research project funded by Higher Education commission, Islamabad under the National Research Support Program for Universities (NRPU). The authors are very thankful to HEC, Islamabad, and Mehran University of Engineering & Technology, Jamshoro, Pakistan, for providing the research facilities and the environment to conduct this research possible.

REFERENCES

[1] Eckelmann, W., Baritz, R., Bialousz, S., Bielek, P., Carre, F., Houšková, B., Jones, R.J.A., Kibblewhite, M.G., Kozak, J., Le, B.C., Tóth, G., Tóth, T., Várallyay, G., Yli, H.M. and Zupan, M., "Common Criteria for Risk Area Identification according to Soil Threats", European Soil Bureau Research Report No. 20, EUR 22185 EN, pp. 94, Office for Official Publications of the European Communities, Luxembourg, 2006.

[2] 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.

[3] Dahal, R.K., Hasegawa, S., Nonomura, A., Yamanaka, M., Masuda, T., and Nishino, K., "GIS-Based Weights-of-Evidence Modeling of Rainfall-Induced Landslides in Small Catchments for Landslide Susceptibility Mapping", Journal Environmental Geology, Volume 54, No. 2, pp. 311-324, India, 2008.

[4] Barredo, J.I., Benavides, A., Hervas, J., and Vanwesten, C.J., "Comparing Geuristic Landslide Hazard Assessment Techniques Using GIS in the Tirajana Basin, Gran Canaria Island, Spain", International Journal of Applied Earth Observation and Geoinformation, Volume 2, No. 1, pp. 9-23, Elsevier Publications Netherlands, 2000.

[5] Binaghi, E., Luzi, L., Madella, P., Pergalani, F., and Rampini, A., "Slope Instability Zonation: A Comparison Between Certainty Factor and Fuzzy Dempster-Shafer Approaches", Natural Hazards, Volume 17, pp. 77-97, Copernicus Publications Italy, 1998.

[6] Carrara, A., Guzzetti, F., Cardinal, M., and Reichenbach, P., "Use of GIS Technology in the Prediction and Monitoring of Landslide Hazard", Natural Hazards Volume 20, pp. 117-135, Copernicus Publications Italy, 1999.

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

[8] Leventhal, A., and Withycombe, G., "Landslide Risk Management for Australia", The Australian Journal of Emergency Management, Volume 24, No. 1, pp. 42-52, Australia, 2009.

[9] Cardinali, M., Reichenbach, P., Guzzetti, F., Ardizzone, F., Antonini, G., Galli, M., Cacciano, M., and Salvati, P., "A Geomorphological Approach to the Estimation of Landslide Hazards and Risks in Umbria, Central Italy", Natural Hazards and Earth System Sciences, Volume 2, pp. 57-72, Copernicus Publications, Italy, 2002.

[10] Vanwesten, 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.

[11] Castellanos, A.E., and VanWesten, C.J., "Qualitative Landslide Susceptibility Assessment by Multicriteria Analysis: A Case Study from San Antonio del Sur, Guantánamo, Cuba", Geomorphology, Volume 94, pp. 453-466, Elsevier Publishers, Netherlands, 2008.

[12] 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, Netherlands, 2008.

[13] Sato, H.P., Hasegawa, H., Fujiwara, S., Tobita, M., Koarai, M., Une, H., and Iwahashi, J., "Interpretation of Landslide Distribution Triggered by the 2005 Northern Pakistan Earthquake Using SPOT 5 Imagery", Landslides, Volume 4, pp. 113-122, Springer Berlin/ Heidelberg, Germany, 2007.

[14] Kamp, U., Owen, L.A., Growley, B.J., and Khattak, G.A., "Back Analysis of Landslide Susceptibility Zonation Mapping for the 2005 Kashmir Earthquake: An Assessment of the Reliability of Susceptibility Zoning Maps", Natural Hazards, Volume 54, pp. 1-25, Copernicus Publications, Italy, 2009.