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Identification Of Landslides Prone Vulnerable Zones Using Geographical Information Systems In Balakot, Pakistan

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Abstract: The serious concern in identifying vulnerable zones is consideration of either one of the aspects, human lives or infrastructure but both should be taken inn account for predicting accurate vulnerable zones. This research has considered the both type of control event parameters to detect the different landslide probe vulnerable zones in Balakot, Pakistan where on 8 October 2005, a terrible earthquake induced various landslides which not only killed human being but also ruined entire city. This research is Geographical Information systems (GIS) based, applied, qualitative using Heuristics approach and quantitative using weight of comparison matrix method to justify the enveloped criteria and its weight with standard results. The different techniques of (GIS) e.g. sub-setting the data, vectorizing the grid data into vector data, classification, and map calculation have been utilized. The conclusion of this reasecrh was detection of different levels of vulnerable zones into five classes such as very high, high, moderate, low and no vulnerability zones. It is assure that this type of detected different vulnerable areas can be useful for the decision makers to redevelop the region in future so that human live and socoio-ecoomic infrastructure may be saved for future.

Keywords: Landslides, vulnerability, Socio-economic set up, human population, GIS, Balakot

1. INTRODUCTION

The vulnerability of slope failures with different terrain conditions have also been studied as pace of destruction of different elements such as human population, residential and commercial buildings, life line network, roads, rivers banks and railway bridges at detain time with probable phenomena (Varnes , 1984). Furthermore, it has been studied quantitatively (Galli *et al.*, 2007) as degree of damage to certain constituents with certain amount in a certain locations. Vulnerability is focused by two ways; nature and human induced. Nature induced also known as direct damage (Alcantara, 2002) vulnerability studies the occurred damages by the control event parameters of nature while human induced focuses such factors which are influenced by human activities (Cardinali, *et al.*, 2002), while the human induced vulnerability is known as indirect damage. The indirect damage is assessed by using comparative study between happened damage and real worth of the influenced structure (Blahut *et al.*,2010) using tempo-spatial digital data of the previous landslide occurrences (Irigaray, *et al.*,2007). This type of study can be done on any scale such as small and large while small scale model would be comparatively large to large scale model defining every element in detail for understanding the decision makers. It has also be seen suggested that very small scale ranging from 1:10,000-50,000 using qualitative approach may not be applied because of less detailed information of various element at the small scale (Mansour, 2010). It has been practiced to identify the vulnerable zones of landslide in past either considering human lives or socio-economic infrastructure but it has been suggested to consider both aspects for identify accurate vulnerability in the region. However the different types of damage are suitable for different type of occurrences such as direct damage is appropriate for rapid type of fissuring while indirect damage study considers the slow type of landslides (Mansour 2010). Furthermore it was pointed out that the direct damage can be predicted in the fast moving type of landslides while indirect damage is predicted for slow moving type of vulnerability using various control event parameters e.g., built in system including residential commercial, official and tourists places (Cardinali, *et al.*, 2002) roads, railways and lifeline network (Galli, *et al.*,2007) supply system (Van Westen *et al.*, 2006) and nearness to rivers, streams and catchments areas, roads, railways etc.

This research has been conducted using Geographical Information Systems (GIS) techniques for identifying different vulnerable zones of landslide

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probabilities in Balakot Pakistan which is landslide prone areas due to the slope fissuring in past which kill many people and destroy millions of properties. Furthermore, this research study is applied from qualitative purposes using Heuristics method to develop different levels of vulnerable zones detecting specific areas. The vulnerability criteria has also been developed which has been justified using one of the mathematical method known as weight of comparison matrix method in the different intensity of assigned weight to the parameters have been justified .

This is assured that this sort of predicted landslide vulnerability in Balakot Pakistan can save human lives and infrastructure and be helpful to the different types of decision makers to mitigate the probable hazard, vulnerability and risk in the future.

2. Landslide Vulnerabilities due to Damage occurred in Balakot

A terrible earthquake with magnitude of 7.6 triggered landslide disaster on 8 October 2005 in northern areas of Pakistan **(as shown in Fig.1),** including one of the tourist cities, Balakot **(as shown in Fig.2)** which was completely damaged and many people were killed (Zaré *et al.*,2009).

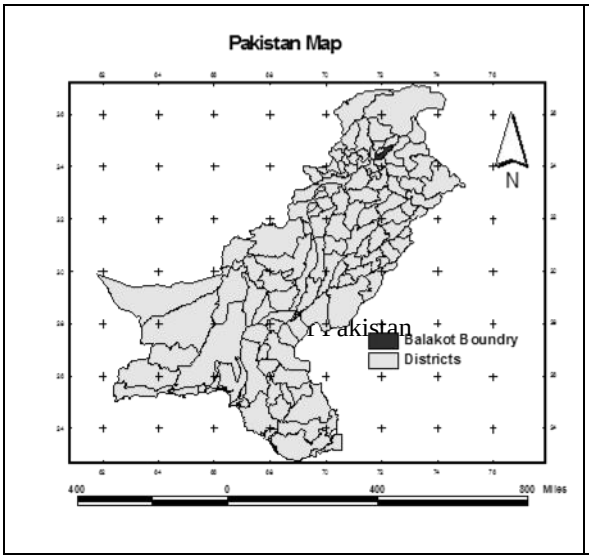

Fig.1. Northern areas of Pakistan

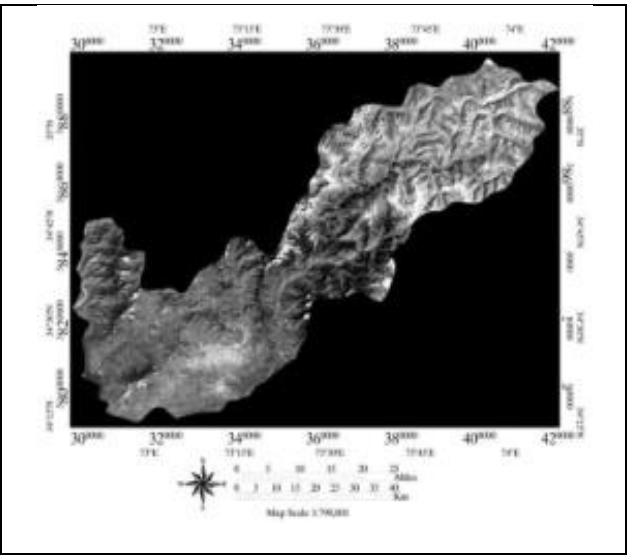

Fig.2. Map of Balakot

3. METHODOLOGY

The different areas such as Balakot city, Ghari Habibullah, Oghi, Sri Paya, Shogran, kawai, Kaghan, Paras, Phagal, Siaful Malook Lake, Sharan, Kunar River, lalazar, Malka parbat, Naran, Moosa Ka Musiala, Lala sar, Babusar Parse, and Jalakhad Nala were entirely destroyed due to the landslide disaster. The triggered landslides in Balakot were collected by photographs as shown in **(Fig. 3)**.

Fig. 3 Landsliding in Balakot, (Owen *et al.*,2008).

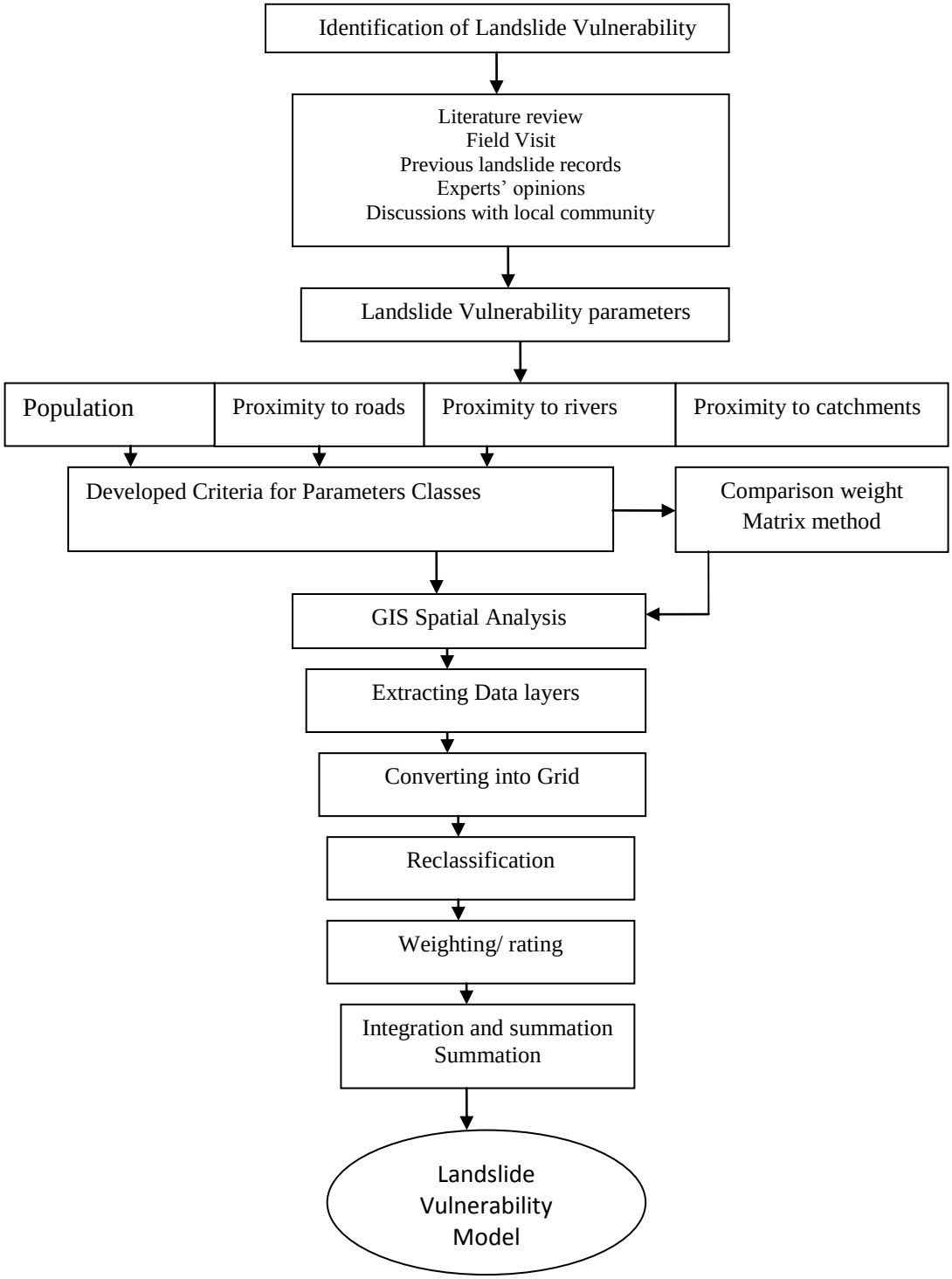

Fig. 4. Landslide vulnerability Model Methodology

4. landslide vulnerability criteria and Parameters Identified

Table 1. Landslide Vulnerability Criteria and Parameters

Criteria	parameters
Hydrology	Rivers, stream, catchments, water bodies
Land over	vegetations, forest
Land Use	Human Population, roads, buildings, railways etc.
Proximity considerations	pulation Proximity, Roads Proximity, Rivers Proximity , Catchment proximity

After that, the different levels of landslide vulnerability zones have been developed as shown in **(Table 2).**

Table2. Landslide Vulnerability Levels

No	Parameters	Very High Vulnerability	High Vulnerability	Moderate Vulnerability	Low Vulnerability	No Vulnerability
1		0-100m	100-800m	800-1200m	1200-1500	>1500m
2		0-200m	200-5000m	500-1200m	1200-1500m	>1500m
3		0-100m	100-800m	800-1200m	1200-1500	>1500m
4	Catchments proximity	0-100m	100-800m	800-1200m	1200-1500	>1500m

5. Justification of landslide Vulnerability Criteria using Comparison of weight Matrix method

The developed criteria always remain biased and subjective. In this research paper also, the baseness and the subjectivity of the developed Landslide vulnerability criteria has also been compensated using comparison of weight matrix method (Malczewski, 1999) as shown in **(Table 3).**

Table 3. Vulnerability factors Matrix weight of different factors

Factors	Catchments Proximity	Rivers Proximity	Population Proximity	Road Proximity	(λ)
Catchments Proximity	1	5	4	7	3.995
Rivers Proximity	1/5	1	4/5	7/5	4.397
Population Proximity	1/4	5/4	1	7/4	4
Road Proximity	1/7	5/7	4/7	1	4.012

The value for the lambda (λ) is simply the average value of the consistency vector

λ = wi +wi +wi +wi +wi…wn /wn= 4.101.

Hence Consistency ratio has also been found using

Eq.1,

CI = ((λ-n) / (n-1)

(1)

CI = 0.034

Further more, the consistency index has also been known using Eq.2.

CR=CI/RI (2)

CR = 0.034 / 0.90

CR = 0.03 which is < 0.10.

The found criteria are less than value of 0.10 which justifies that it is not subjective.

6. RESULT

The landslide vulnerability model has been developed using landslide vulnerability criteria and The vulnerability levels have been generated into four categories (as shown in Table 2) as very high vulnerability, high vulnerability moderate vulnerability low vulnerability as mentioned in **(Fig. 5).**

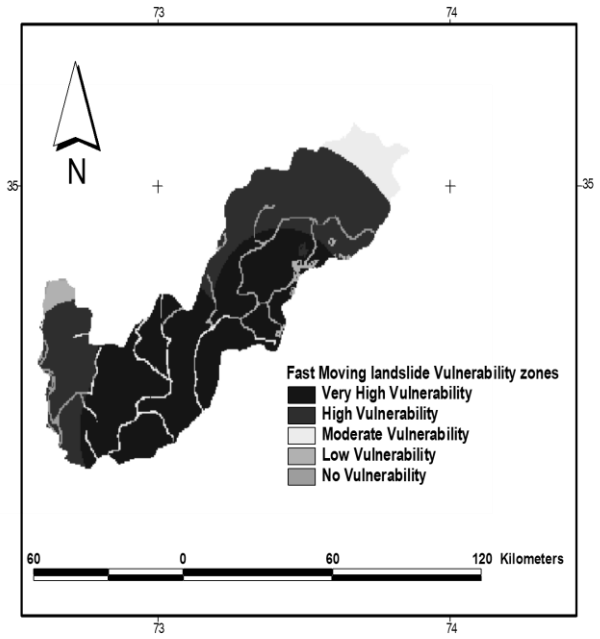

Fig.5. Landslide Vulnerability Model

The predicted landslide vulnerability locations have been mentioned in Table 4. areas haven described as shown in **(Table 4).**

Table 4. Predicted Landslide Vulnerability areas

No.	Tsunami Vulnerable Zones	Names of Predicted Tsunami Vulnerable Zones
1	Very High Vulnerable Areas	Ghari Habibullah, Atter Shabiha, Jalakhad Nala, Burawi, Batal Sum, Oghi, Mansehra City., Balakot city, Moosa Ka Masiala, Malka parbat, lalazar, paras, sogran, sri Paya, Kawai.
2	High Vulnerable Areas	Nill
3	Moderate Vulnerable Areas	Nill
4	Low Vulnerable Areas	Nill
5	No Vulnerable Areas	Nill

7. DISCUSSIONS

Reliable prediction of vulnerable zones needs the considerations of both aspects; human lives and socio-economic set up together. In such cases, if one of the factors has been overseen, the accuracy of identification of vulnerable zones can be created this will badly influence on the quality of prediction of vulnerability zones. Such inaccurate predictions can create various confusions and complex for the different decision makers during implementing such type of predictions. The justification of the developed criteria and suitable approaches may be hybrid, qualitative and quantitative can also create qualitative predictive results in identifying the vulnerability, hazard and risk zones.

8. CONCLUSIONS

The identification of vulnerability in Balakot has hlepd to sort out different critical vulnerable regions such as Very High Vulnerable Areas are Ghari Habibullah, Atter Shabiha, Jalakhad Nala, Burawi, Batal Sum, Oghi, Mansehra City., Balakot city, Moosa Ka Masiala, Malka parbat, lalazar, paras, sogran, sri Paya, Kawai while the rest of areas except tee aforementioned are free from vulnerability. This research is pure and applied. The mathematical approach, known as saaty scale of importance using weight of comparison matrix was also utilized to justify the subjectivity of the developed criteria. It is believed that, the different predicted vulnerable zones can be useful for the decision makers for redevelopment of the region in future.

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