MANAGEMENT OF GEOENVIRONMENTAL PROBLEMS (NATURAL HAZARDS). A METHOD FOR LANDSLIDE HAZARD ASSESSMENT USING GEOGRAPHICAL INFORMATION SYSTEMS (G.I.S)

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Abstract

Natural disasters and especially landslides are common at several regions in Greece, having both environmental impact and repercussions on economy. G.I.S. can help us integrate our knowledge on landslides, proceed to effective planning and develop decision making tools. In this paper a new method appropriate for evaluation and management of landslide hazard is presented. The main stages of the method are the landslide inventory, hazard mapping and statistical analysis. All parameters affecting hazard mapping (geology, geotechnical conditions, climate, topography, land use, etc.) are discussed with regard to their role on landslide risk evaluation method and refer to the flow diagram.

Introduction

During the last few years the approach on geoenvironmental problems has changed with science trying to come up with satisfactory ways to predict natural disasters rather than trying to take remedial action after a catastroph. The primary objective is to minimise casualties and economic repercussions and not to stop development projects.

One of the most common, if not the most common, natural hazard in Greece is landslides. Broadly speaking landslides are connected with a number of parameters such as geology (faults, hydraulic conductivity, strength), tectonics (discontinuities), seismicity, climate (rainfall), land use, topography, drainage (rivers) and human influence.

The difference between landslide hazard and landslide risk, must be emphasised. The former refers to the probability of occurrence of a potentially damaging phenomenon within a specified time and area and the later is a measure of the damages caused from that phenomenon. Risk assessment may be achieved by the means of a detailed spatial division of the earth's surface into areas of different levels of threat (microzonation) (JONES, 1993). The method of landslide hazard assessment and the hazard map are useful tools for the preliminary stage of a risk assessment.

Thematic map analysis - flow diagram

Landslide hazard assessment is based on processing thematic maps which cover the most important parameters affecting landslides. The parameters encompassed by the method are the following:

- soil - rock strength
- permeability
- faults
- seismicity
- river classification
- erosion (downcutting)
- rainfall
- slope aspect
- slope angle
- discontinuities dipping angle
- discontinuities direction
- human influence
- vegetation

The flow diagram of the method is presented in Fig. 1. The first step in order to apply the method is to select a suitable scale which is proposed to be between 1:25,000 and 1:100,000.

Geotechnical maps, with regard to strength of geological formations, which are based on existing geological maps for a given area must be coupled with extensive laboratory and in situ testing. This way quantitative evaluation of strength would be acceptable.

Flow Diagram

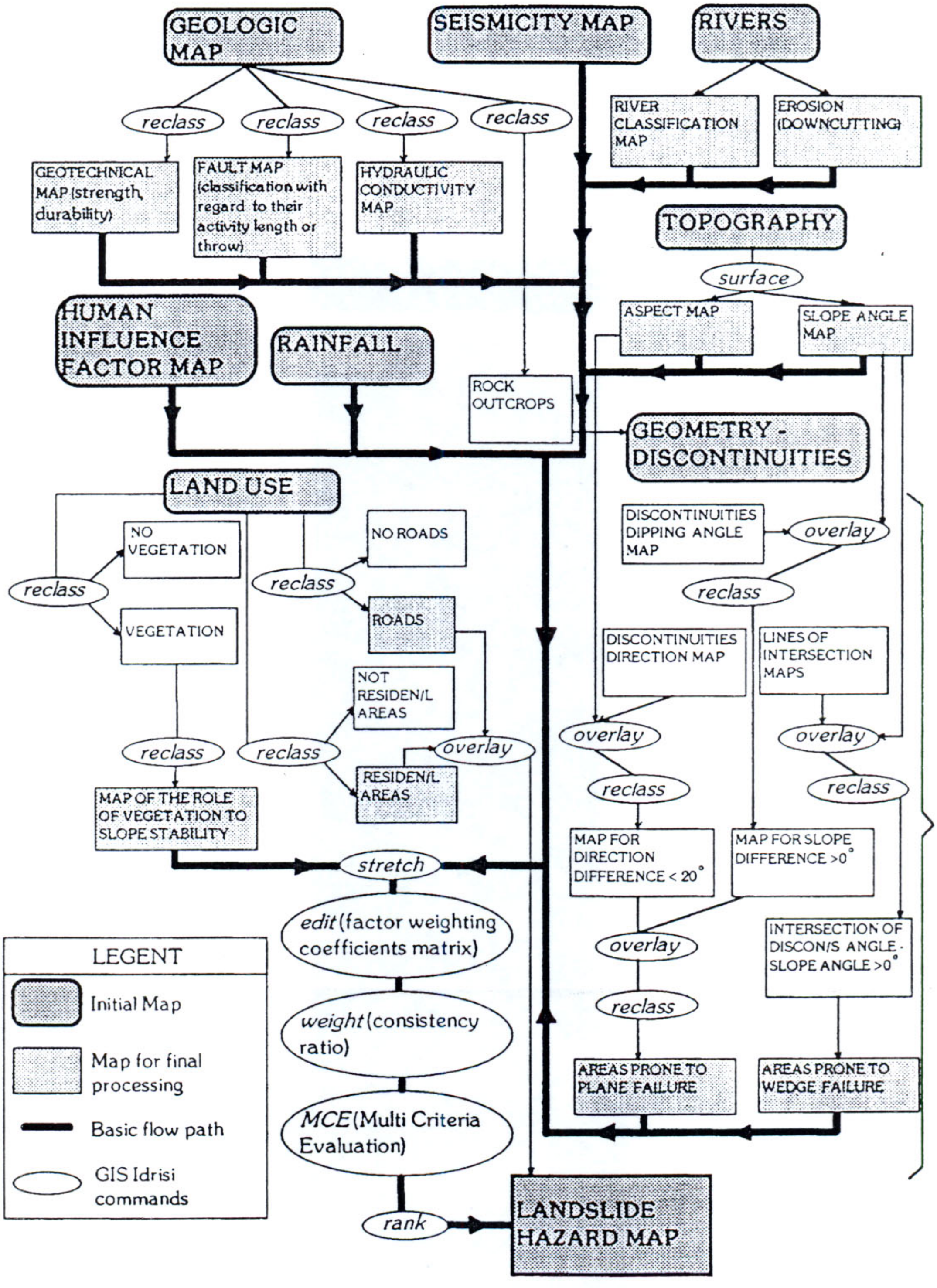

Fig. 1

Parameters such as opening, length, and filling material of discontinuities are not dependent on lithology to the extend they are dependent on deformation conditions and the distance away from fault zones. Identification of fault zones can be done on field or with aerial photographs and then introduced in the Landslide Hazard Assessment Method by creating an appropriate buffer around faults. The faults can then be classified according to their activity (active, probably active, not active), their throw or their length, based on geological criteria.

There is a relation between the presented parameters affecting landslide hazard and the rock mass characteristics which are not included in the method. However, rock mass characteristics such as intact strength, weathering, discontinuity spacing and orientation are included secondary through the Geotechnical Map and the Fault Map. Durability is also related to lithology because durable rocks which not form thick weathering mantle are less prone to deep seated landslides, while alluvium, Quaternary and flysch formations are more prone to landsliding.

Slope angle together with the geometry of the failure surface are the most important parameters influencing the distribution of gravitational forces. The Slope Angle Map and the Slope Aspects Maps are obtained directly from the Topographic Map and then they can be classified in classes. Fernandez (1994) recommends 6 classes for the Slope Angle Map and 16 classes for the Aspect Map.

Geometry of Slope in relation with Geometry of Discontinuities can identify areas with rock outcrops more prone to landsliding. In soil slopes the critical parameter remains the soil strength along the slip surface. The geometrical characteristics of different discontinuity sets are revealed from detailed in situ investigation and hemispherical projections. Then the data base of representative point measurements can be converted into a map by using Thiessen polygons. The procedure in order to identify areas prone to wedge and plane failures is presented in the flow diagram. Areas prone to toppling failure can be identified similarly. Overlay of lines of intersections on the slope angle map produces a huge amount of data and therefore the worst case for each polygon is selected to minimise data processing.

Hydrogeological conditions are significant to landslide potential since they determine pore water pressures. The Landslide Hazard Assessment Method from the large category of the hydrogeological conditions includes Permeability or better Hydraulic Conductivity and Vegetation. Soils with high hydraulic conductivity are better drained, will not built up pore water pressures and therefore are less prone to landsliding compared with low hydraulic conductivity soils which favour high pore water pressures and water levels. Vegetation controls water table levels, influences erosion rate and also stabilises the ground through the roots. The role of each vegetation type and infertile land to slope stability in a given area must be investigated in order to classify all vegetation types with respect to slope stability.

Human activities usually promote slope instability. For example cultivated land is supervised regularly while abandoned or recently burnt areas are more prone to landsliding. Moreover, human influence comprises steep slopes in road cuttings, excavations in quarries, mines etc. All the above mentioned parameters can be grouped together and form the Human Influence Factor Map.

Rainfall and Seismicity Maps are prepared based on climatic and seismic data. For example, a Seismicity Map relative to slope stability may include expected peak ground accelerations or intensities (Modified Mercali intensity) (HUSEIN et al, 1995) or densities of earthquakes of a given magnitude. Earthquakes may result to slope failure over a large area and are one of the most important landslide triggering mechanisms. During earthquakes low slope height - high angle forms show much greater decrease in stability than that anticipated from the increase in pore water pressures (MURPHY, 1995). With regard to the Rainfall Map it refers to precipitation per year or recurrence interval for rainfall events with given height.

Rivers should be digitised in different levels according to their grade. Low grade streams are prone to landsliding. Erosion and Downcutting indicate tectonic activity and are geomorphologic parameters affecting landslides.

Weigthing

The parameters used for final processing are weighted using weighting coefficients. Geometry - Discontinuities are the only constraints which means that if there is not favourable inclination (dipping) and orientation of rock slopes, wedge and planar failures can not be made possible even if all other parameters are favourable.

The Landslide Hazard Assessment Method can be checked against a landslide inventory and by simple statistics or multivariate analysis the significant criteria to slope instability can be identified.

For the final presentation Roads and Residential areas are overlapped on the hazard map. This way a simple risk map can be produced.

Conclusions

The Landslide Hazard Assessment Method can be used for general planning and emergency action planning. G.I.S. can help not only landslide hazard mapping but also data base development for integrated risk mapping according to local characteristics. Further refinements of the Landslide Hazard Assessment Method would include slope height and geological structure.

Weighting of the parameters affecting landslides, back analysis and geostatistical methods to evaluate uncertainty are essential intermediate stages in order to develop a decision making system.

Landslide Hazard Assessment Method is adaptable, quick and can identify landslide hazard over extensive areas. Synthesis of a decision making system, which would be used for planning and protection and, at the same time, would appreciate local conditions, is absolutely feasible.

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