LANDSLIDE PREDICTION USING ARTIFICIAL NEURAL NETWORKS

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Abstract

Landslides are the most recurrent and prominent disaster in Sri Lanka. Sri Lanka has been subjected to a number of extreme landslide disasters that resulted in a significant loss of life, material damage, and distress. It is required to explore a solution towards preparedness and mitigation to reduce recurrent losses associated with landslides. Artificial Neural Networks (ANNs) are now widely used in many computer applications spanning multiple domains. This research examines the effectiveness of using Artificial Neural Networks in landslides predictions and the possibility of applying the modern technology to predict landslides in a prominent geographical area in Sri Lanka. A thorough survey was conducted with the participation of resource persons from several national universities in Sri Lanka to identify and rank the influencing factors for landslides. A landslide database was created using existing topographic; soil, drainage, land cover maps and historical data. The landslide related factors which include external factors (Rainfall, Number of Previous Occurrences and Influence of Construction) and internal factors (Soil Material, Geology, Land Use, Curvature, Soil Texture, Slope, Aspect, Soil Drainage, and Soil Effective Thickness) are extracted from the landslide database. These factors are used to recognize the possibility to occur landslides by using an ANN. The network acquires the relationship between the factors of landslide and its hazard index during the training session. This model with landslide related factors as the inputs will be trained to predict three classes namely, ‘landslide occurs’, ‘landslide does not occur’ and ‘landslide likely to occur’. Once trained, the model will be able to predict the most likely class for the prevailing data. Experiments show a high prediction rate with 83% accuracy. This research indicates that the proposed mechanism could be used as a strong decision support system to predict landslides efficiently and effectively.

Keywords: Landslides Prediction, Artificial Neural Networks, Landslide related factors

1. Introduction

Landslides are a common natural phenomenon in many part of the world, especially in hilly or mountainous terrains. A landslide event is defined as "the movement of a mass of rock, debris, or earth (soil) down a slope (under the influence of gravity) (cruden, 1990).The word "landslide" also refers to the geomorphic feature those results from the event. Other terms used to refer to landslide events include; mass movements, slope failures, slope instability and terrain instability. In spite of the simple definition, landslide events are complex geological/ geomorphologic processes and therefore difficult to classify. The most commonly used landslide classification system is based upon the material type and the type of movement described by (cruden and varnes , 1996).

Landslide is a general term for a wide variety of down slope movements of earth materials that result in the perceptible downward and outward movement of soil, rock, and vegetation under the influence of gravity. The materials may move by falling, toppling, sliding, spreading, or flowing. Some landslides are rapid, occurring in seconds, whereas others may take hours, weeks, or even longer to develop.

Many factors contribute to landslides, including geology, gravity, weather, groundwater, wave action, and human actions. Although landslides usually occur on steep slopes, they also can occur in areas of low relief according to bandara et al. (1994). Landslides can occur as ground failure of river bluffs, cut and-fill failures that may accompany highway and building excavations, collapse of mine-waste piles, and slope failures associated with quarries and open-pit mines. Underwater landslides usually involve areas of low relief and small slope gradients in lakes and reservoirs or in offshore marine settings.

Typically, a landslide occurs when several of these factors converge. Every year in Sri Lanka especially in mountain regions like Badulla district, landslides damage many houses and cause millions of rupees damage to buildings, roads, railways, pipelines, agricultural land and crops.

An effective solution to minimize the damage from a landslide will be a mechanism for early prediction. If we can come up with a prediction model, it will be more benefit to individuals as well as the whole society. This research is to develop a model to predict landslide disasters using artificial neural network and the study is mainly focussed on the landslides in the Badulla district.

2. Literature Survey

Sri Lanka is an island in the northern Indian Ocean just south of southernmost part of India and extends in latitude form approximately 060 N to 100 E and in longitude from approximately 800 N to 820 E with an extent of about 65,000 km2. Adams (Adams, 1929) was the first to draw attention to the existences of three well-marked plains of erosion cut in the precambrian rocks of Sri Lanka. These "three terraces" present three successive stages of denudation brought about by successive uplift of Island as a whole. On morphological grounds Wadia (Wadia, 1943) rejected this "erosion

terrace theory" and postulated that the three peniplains are the result of successive bedrock uplifts. The recent detailed structural and tectonic mapping of central highlands indicates that in addition to the vertical epirogenic movements of the southerly drifting manipulate of Sri Lanka, there are horizontal thrust developed regionally and a series of strike slip faults along mega-lineaments (Vitanage, 1994). Some of the lineaments appear to be active and some of the older highly weathered lineaments are commonly associated with large destructive recurrent landslides. Since there are no simple mechanisms to foresee instabilities, monitoring is the most appropriate mechanism to understand their behavior.

The government during this period was aroused the need of early warning systems and it came up with atmospheric models that forecast the temporal and spatial distribution of rainfall which is a useful alternative source of rainfall information. This is now increasingly being used in hydrological applications though it mainly focuses on rainfall information.

Landslide disaster risk reduction demands integration of a number of disciplines associated with various aspects of physical and hydro-meteorological characteristics of a region as well as social and cultural dimensions. Therefore, landslide disaster mitigation requires collective and corporative efforts of all relevant r&d institutions lead by strong executing organizations of the country.

One of the mechanisms that evolved during the disaster in May 2003 and an implementation of landslide disaster mitigation works, was the establishment of a ad-hoc group named "operation professional combine" established at Rathnapura, the most affected area. This was carried out in accordance with the action plan proposed by the Central Engineering Consultancy Bureau (CECB) at the council meeting of the Disaster Management Committee held in Colombo, 28th May 2003.

An early study on this subject was carried out by Lee et al. (2004). The purpose of this study was to develop landslide susceptibility analysis techniques using an Artificial Neural Network (ANN) and to apply the newly developed techniques to the study area of Boun in Korea.

Landslide locations were identified in the study area from the interpretation of aerial photographs, field survey data, a spatial database of the topography, soil type, timber cover, geology and land use. The landslide-related factors (slope, aspect, curvature, topographic type, soil texture, soil material, soil drainage, soil effective thickness, timber type, timber age, and, timber diameter, timber density, geology and land use) were extracted from the database. Using those factors, landslide susceptibility was analyzed by artificial neural network methods. Maps constructed in a vector format spatial database using the GIS software ARC/INFO were used for the application of ANN methods.

The Geological Society of London (Fuxiang and Lan, 2002) did a research to come up with a prediction model for landslide disasters using Artificial Neural Networks and Geographic Information Systems. According to this research it was not possible to use ANNs and GISs effectively to predict landsides objectively but it showed the significance of spatial distribution of the occurrence of landslides resulting in the development of a landslide distribution database.

In Philippines, (Lee1 and Evangelista, 2006) did a research about landslide-susceptibility analysis techniques using an Artificial neural network and a Geographic Information System (GIS) applied to the Baguio City. Data preparation involved the digitization or creation of a GIS database which included the topographical, geomorphic- logical, geological and land cover data. In the verification of landslide-susceptibility maps, the Artificial Neural Network showed a very high prediction accuracy of 93.20% in the case of 0 slope.

Landslides are one of the most hazardous natural disasters, not only in Sri Lanka but also in worldwide. The Governments and research institutions worldwide have attempted for years to assess landslide hazards and risks and to determine their spatial distribution. In this research it is expected to develop a model to predict landslides using ANNs and GISs.

3. Data collection and analysis

The primary objective of the study was to identify factors which effect to occur landslides, through a quantitative methodology with a survey based approach. Numerous factors were considered when defining the research sample, but mainly focused on the lessons learned through the literature review. As the main focus of the research was on landslides in Sri Lanka, GIS experts in several universities were selected as the resource persons for the survey.

Data collection was done via the Likert scale questionnaire filled by the representatives of the selected universities. Data were collected under four categories namely, Topography, Soil, Wood and Other factors. By referring to researches done before, variables were identified. A questionnaire was prepared to gather information for these variables. The variables defined describe the factors that affect for landslides. All the variables were selected from past researches.

Before preceding, all the variables were laid down before a panel of experts for evaluation. The panel of experts selected the most influential and relevant factors and selected the most relevant and important factors affecting for landslides. A likert scale was used for this rating. Respondents were allowed to rate each factor in a scale from 1 to 5 according to their preference. Number 1 was for 'totally disagree' variables and number 5 was for 'strongly agree' variables. Selecting respondents for the data collection survey was also important to maintain the quality and standards of the findings. Therefore, a dedicated approach was practiced when selecting respondents from each university. Because their perception was evaluating the variables and the output was totally based on it. In total 200 copies of the Questionnaire were distributed among four universities, and 126 of which were duly filled and returned to the authors. Professors, Senior Lectures, Lectures, Civil Engineers and PhD students were among the experts who responded to the survey.

A reliability analysis was carried out to determine the consistency and stability of data. Cronbach's alpha which is the coefficient for reliability was analyzed on each data set. Reliability of a measure was tested for both consistency and stability. Consistency indicates how well the items measure a concept hanging together as a set. Therefore, to ensure the reliability of the data Cronbach's alpha coefficient was calculated.

Submitting the data for factor analysis establishes a factorial validity. This confirmed that, the theorized dimensions have been emerged. Though variables indicated in each category were selected through literature and confirmed by a panel of experts in order to identify the most relevant factors, a factor analysis was carried out.

The first objective of the research was achieved from descriptive statistics. A descriptive frequency analysis was done and the according to the Figure 1, the mean values of the variables were of 'distributed' nature. Landslides were occurring due to all the factors that we have identified above. The most prominent factor for occurring landslides in Sri Lankan context is the rain fall which scores the highest mean value. Soil material is also highly significant. In factor analysis we ignore the variable 'earth quakes' which had a minus component in the matrix because in Sri Lankan context it is not significant. Finally it was possible to identify twelve most prominent factors which affect to occur landslides. These factors are

- Rain Fall
- Soil Material
- Geology
- Land Use
- Curvature
- No of Previous Occurrence
- Soil Texture
- Slope
- Aspect
- Influence of Construction
- Soil Drainage
- Soil Effective Thickness

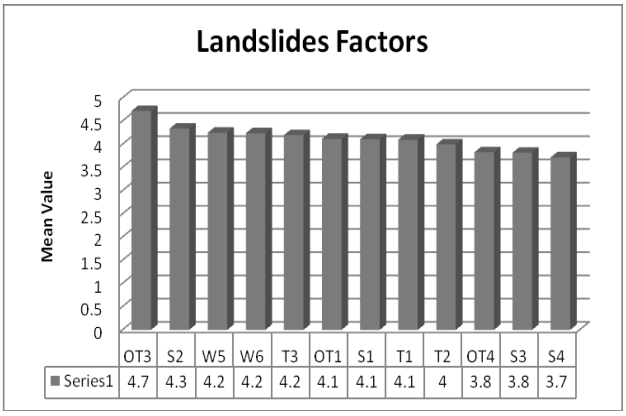

Figure 1: Mean value and landslide factors

4. Artificial Neural Network

The first step towards Artificial Neural Networks was introduced in 1943 when Warren McCulloch, a neurophysiologist, and a young mathematician, Walter Pitts, published a paper on how neurons might work. They modelled a simple neural network with electrical circuits.

Since a very high uncertainty is involved in predicting landslides, a Neural Network is a better solution as it handles uncertainty to a very high degree to prediction of Landslide Disasters as a dynamic prediction model. This is an effective solution when it is difficult to build the relationship. First of all, integration of remote sensing data or GIS data is convenient. Secondly there is no need a specific statistical variable. Thirdly, accurate analysis is possible through training area datasets which is a few because of pixel based calculations. Neural Network can process simultaneously qualitative and quantitative data. Therefore, a Neural Network is a good candidate to establish these models.

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. A GIS was used to efficiently analyze the vast amount of data. This survey focused on exploring the methods of construction of a specific database using GIS.

The benefits of integrating GIS and artificial neural network are efficiency and ease of management, input, display and analysis of spatial data for landslide susceptibility analysis.

5. Data using GIS

Landslide database was created which includes external factors (Rainfall, Number of Previous Occurrences and Influence of Construction) and internal factors (Soil Material, Geology, Land Use, Curvature, Soil Texture, Slope, Aspect, Soil Drainage, and Soil Effective Thickness). Data from metrology department and historical data has used for external factors and existing maps were used to extract internal factors.

In this study aerial photographs were used to detect landslides locations. In the study area total of 224 landslides were mapped in an area of $224km^{2.}$ Twelve factors were considered in landslides prediction. These factors were extracted from the landslide database. The internal factors were transformed into a vector type using a GIS. A digital elevation model was created using topographic map. Then, the slope, aspect and the curvature were calculated. Using the geology map the lithology was extracted. Eventually, the land use data were classified. The soil map was used to extract soil drainage, soil effective thickness, soil texture and soil material.

All the above data were converted to a raster grid with 10 meter ×10 meter cells for the application of the artificial neural network. The area has 2018 rows by 1390 columns with 224 cells of landslide occurrences.

6. Experimental Results

First training data was selected Three classes of training data were selected as ‘landslide occurs’, ‘landslide does not occur’ and ‘landslide likely to occur’ Cells from each of three classes were randomly selected.

Three layered feed forward neural network was implemented. Figure 2 shows architecture of Artificial Neural Network Model which include 12×9×2 structure. Trial and error approach was used to find suitable number of hidden layers and nodes. In this study, used tan sigmoid transfer function in each layer. During the training process, the connection weights of the neural network were initialized with some random values. The training data set was input to the neural network after doing the normalization. Then, the connection weights were adjusted according to the error back-propagation learning rule. We have done several changes for the network architecture, based on the following criteria finalized the network.

- Number of hidden layers.
- Optimum number of hidden nodes.
- Momentum factor.
- Learning Rate parameter.

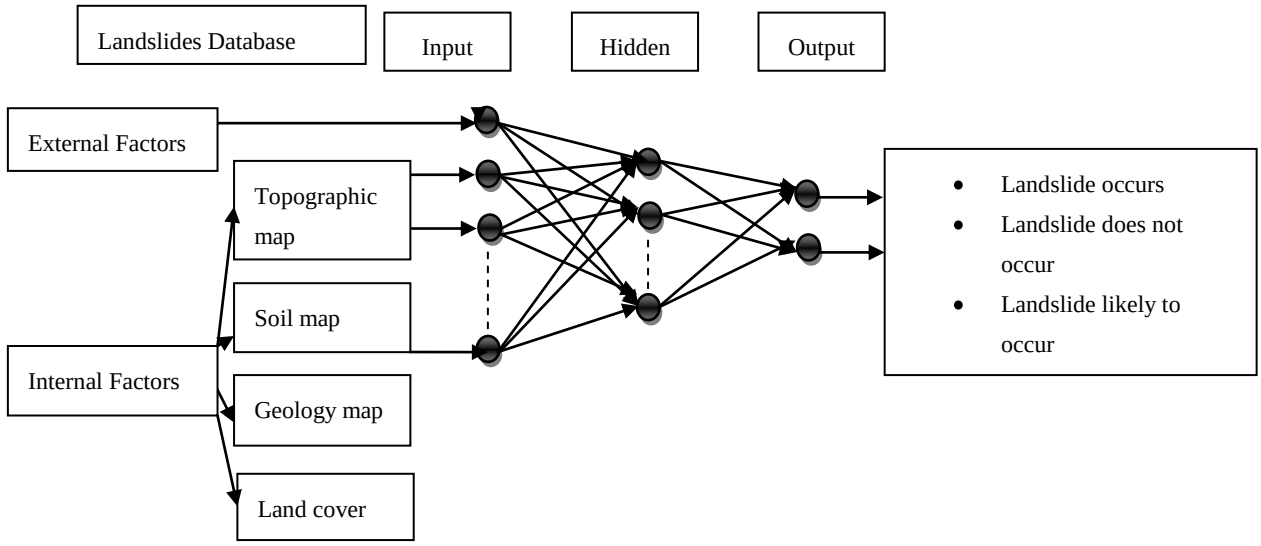

Figure 2: Artificial Neural Network Model

All the input data were normalized in the range 0.1-0.9. This model which consist of the identified factors is trained to predict three classes namely, ‘landslide occurs’, ‘landslide does not occur’ and ‘landslide likely to occur’. Once trained, the model is able to predict the most likely class for the prevailing data. Subsequently, the network was tested with the training set and the test data set separately and the accuracy was calculated. The network performs at 83% accuracy. The results are summarized in Table 1.

Table 1. Results

Data	Prediction Rate	Prediction %
Training Set	10/12	82
Test Set	10/12	83

7. Conclusion

This research was aimed at developing a landslide prediction system as Landslides are the most recurrent and prominent disaster in Sri Lanka. Based on this research twelve factors were initially identified as the most relevant to influence landslides. It is important to note that the most significant factor that influence to occur landslides is rainfall which has the highest mean value in analysis and the other more prominent factors were Soil Material, Geology, Land Use, Curvature, No of Previous Occurrences, Soil Texture, Slope, Aspect, Influence of Construction, Soil Drainage, and Soil Effective Thickness.

The prediction model was implemented using an artificial neural network which performs at 83% accuracy. Results show that artificial neural networks can be used to develop an effective decision support system for landslide prediction.

Future Work

The research will be continued to implement the predicted hazard maps using the result of artificial neural network which will be thoroughly tested in order to predict landslides hazard maps with a high accuracy.

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