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Easy To Use Remote Sensing and GIS Analysis for Landslide Risk Assessment.

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الخلاصه

الكثير من البلدان حول العالم تعاني من المخاطر الطبيعية، فهي تؤدي الى الكثير من الخسارة في الممتلكات والارواح، نحن لا نستطيع ان نمنع حدوث مثل هكذا مخاطر لكن، من الممكن تقليل اثارها والمحافظة على ارواح الناس وتقليل الخسارة بالممتلكات. العديد من الطرق اجريت لتخمين النموذج المناسب لتقييم انزلاق الارض. خرائط الحساسة للانزلاق الارضي انشأت من خلال دمج بين معلومات التحسس النائي مع امكانية نظم المعلومات الجغرافية .لقد ناقشنا مختلف انواع الخوارزميات والمعاملات لنمذجة توقع وتقييم خطر الانزلاق الارضي مثل دعم ناقلات الالة ،شجرة اتخاذ القرار ،التكيف لنظام الاستدلال العصبية الغامض، عملية التحليل الهرمي وشبكة الاعصاب الاصطناعية، نموذج معملات احتمالية تردد حدوث الانزلاق الارضي، والنموذج التجريبي. الدراسة تقيم مختلف المعاملات المسؤولة عن حدوث الانزلاق الارضي وترجيح كل معامل واهميتها لاحتمال نشاط انزلاق ارضي. طريقة عملية التحليل الهرمي ، نموذج ترجيح الدليل، و الانتشار العكسي قد طبقت لترجيح العوامل .وجدنا ان استخدام طريقة شبكة الاعصاب الاصطناعية مع اكثر من عشر معاملات سوف تعطي دقة عالية خاصة اذا تم التحقيق بواسطة معلومات حقلية.

كلمات المفتاحية: الاستشعار عن بعد. قابلية خطر الانهيارات الأرضية. شجرة القرارات؛ دعم شاحنات النقل؛ عملية التحليل الهرمي وخصائص التشغيل المتجه.

Abstract

Many countries throughout the world suffered from the natural risks, they cause a large damage in property and loss in human lives, we cannot prevent the occurring of these hazards but, it is possible to reduce their affect in saving human lives and reducing the damage in properties. Several methodologies have been conducted to predict the suitable model for landslide assessment. The susceptibility maps of landslide hazard generated by combining the remote sensed data with the capability of GIS (geographic information system). We discussed different type of algorithms and factors for modeling the prediction of landslide risk assessment such as SVM (support vector machine), DT (decision tree), ANFIS (adaptive neural-fuzzy inference system), AHP (analytic hierarchy process), ANN (artificial neural network), probability frequency of landslides occurrence factors model and empirical model. The study evaluated various parameters that are responsible for landslide occurrence and the weighting for each parameter and its importance to probable of landslide activity. AHP method, Weights of evidence model, and back propagation method have been applied for weighting the factors. We found that using ANN algorithm with more than ten factors will give high accuracy result especially if the validation performs by field surveys data.

Keywords: Remote sensing; Landslide hazard susceptibility; Decision Tree; Support Vector Machine; Analytic Hierarchy Process and Receiver Operating Characteristics.

1. Introduction

During the last three decades, many studies in landslide risk mapping have been published throughout of the world. The landslide risk assessment is one of the series topics in the landslide reviewing literature, simply because the risk assessment is difficult to perform and the landslide is non-linear phenomena. For prediction the landslide risk assessment different methods have carried out. Landslides usually happen due to two types of factors: Triggering factors, such as heavy precipitation events and/or earthquakes, and preparatory conditions such as soil property, slope, topography, land use / land cover, hill slope saturation and vegetation which play important roles in the occurrence of landslides (Farahmand *et.al.,* 2013;Dibs, 2016) .The importance of landslide hazard and risk assessment susceptibility maps has been discussed in many publications. In addition to that, the hydraulic and hydrologic factors such as heavy rainfall return period and hydraulic gradient, which are the main causes of landslides in many countries, were neglected in some GIS analysis. However, studying different approach for landslide prediction maps such as ANN, SVM, DT, empirical model and combination of two approaches) still not been encountered widely in the previous literature (Pradhan and Lee, 2009). For this reason, we covered in this study different landslide hazard and risk assessment susceptibility approaches and then we went through models that have been used for selecting controlling factors, the weighting procedure and finally mapping the landslide hazard susceptibility.

(Roessner *et.al.,* 2000) studied the importance of using Remote Sensing and GIS for landslides risk assessment. They combined the analysis of multispectral satellite data, DEM (Digital Elevation Model) and geological information and they mentioned that there is a lack of geographic information available in Kazakhstan and that affect to the accuracy of their study. They compared between different types of Remote Sensing tools which are available and conclude that it is important to use satellite remote sensing for improving landslide hazard assessment.(Ramakrishnan *et.al.*,2002) developed a TIN (Triangular Irregular Network) model in order to generate the landslide susceptibility map in a GIS environment by using the Arc view 3D analysis; this model was created from the digitized contour map to measure the effect of the causative factors in the landslide prone areas. Four factors were considered for this study. Overlay analysis has been done for weighting. The weight assignment was prepared in a LUT (look up table) and linked with union coverage. A ground validation was done by the derived landslide map. They conclude that success in landslide management can be achieved with a full and comprehensive knowledge of some basic factors including character and magnitude of the mass movement in an area. (Ibrahim ,2004) implemented a model developed by using a logistic regression analysis approach to measure the influence of the causative factor that contributes to landslide hazard. The model is based on previous models used by several researchers. Records of past landslides were captured through the interpretation of aerial photographs while records of recent landslide were collected through field work. Twelve causative factors were considered but the model used was able to analyze only nine of these factors and weighting is conducted using overlay function get a visible correlation between every single landslide to their causative factors. It is established in the study that not all factors are necessarily needed for analysis but the most significant factors which actually reduce the number of factors from 12 to 9. The model gives an accuracy rate of about 77 %. Character and magnitude of the mass

movement in an area are the factors affecting the variation in the relationship between the landslide and their causative factors.

(Lee and Pradhan,2006) improved the accuracy, they have been predicted the landslide hazard and risk susceptibility by employing the model of probability frequency of landslides occurrence factors. There were ten factors involved in their analyzing form the study area, the data that used was integrated from field surveys, satellite images, aerial photographs and topographical and geological data. By combining the remote sensed data and GIS capability as a tool to perform the processing and analyzing of data. The result of frequency ratio model represents that 86.41% and 80.03% the accuracy for susceptibility and hazard mapping respectively. The verification of result conducted by compared the maps of a probabilistic model with the landslides locations dataset. In this research even with the accuracy 86.41% and 80.03% for each of landslide hazard and risk assessment respectively, but still need to improve, that simply because the lack of data that involved in this study, increase the number of factors will increase the probability frequency of landslides and that lead to getting more accurate result.

(Teerarungsigul *et.al.*,2006) proposed a prediction of landslide hazard model using remote sensing and GIS with field geology data. They have been involved nine factors to conduct this study, then they gave these factors weight using probability bivariate analysis which is based on the comparison of each class of each factor with the distribution of landslide in past in order to get the probability of landslide occurrence in each class of each factor. However, they focused on internal factors without accounting the external factors such as the effect of heavy rainfall return period. Five levels of a relative hazard on a landslide susceptibility map were defined to represents the expectation of landslide occurrence based on the conditions of that particular area. The accuracy of their analysis is not mentioned clearly but they conclude that the verification of result conducted by comparison of existing landslide data with landslide hazard maps and the results show satisfactory agreement between them based on combination of reliability and accountability weighted but unsatisfactory agreement if the validation conducted based on reliability only, or accountability weighted only with existing landslide location data.

(JAXA ,2006) developed a Landslide susceptibility map based on satellite and aerial remote sensing data with GIS. Seven physical factors affect the occurrence of landslide were studied. The study conducted for developing multi-temporal GIS database. Weighting factors conduct by a statistical approach of weighted analysis method assessment based on the two methods: the terrain stability model of SINMAP (Stability Index Mapping) and the WAA (Weighted Average Analysis) method of the assessment model. In this study, validation of landslide susceptibility results shows that in SINMAP model the accuracy is significantly depended with the DEM and input soil parameters and on the other hand, the weighted average probabilistic model there is an uncertainty of some combined weighted factor. The lack of complete data base of recent occurrences of landslides reduced the accuracy of this study, as the validation based only on 39 landslides out of 78 case records at their study area. Therefore, complete multi-temporal satellite data is highly needed to overcome such problems and acquire more geographical information for better validation.

(Hong *et.al.*,2007) developed a continuous scale of a global landslide susceptibility index using GIS weighted linear combination based on the causative factors for landslide occurrence. Six factors were considered for the susceptibility analysis and were derived from geospatial remote sensing data and used in conjunction with satellite-based precipitation data to determine places with potential landslide occurrence. Rainfall was identified as a major causative factor for the landslide. A satellite-based, real-time rainfall measuring system is recommended to monitor areas with significant landslide occurrence. Weighting is performed by applying primary and second level weights to the landslide controlling factors so as to combine them, a method known as WLC (weighted linear combination). The accuracy of the susceptibility map is time dependent in other words accuracy increases with time. This study made the factors weighting in two levels and that will make the accuracy of a result and the model the used more satisfactory to use for landslide hazard susceptibility.

(Tassetti *et.al.*,2008) used another model by generated a mathematical model to predict the actual and potential slopes instability, they minimized the number of factors to 5. CF (certainty factor) has been used for weighting these factors, this model is a linear model, the hazard scores based on the instability factors and the coefficients evaluated statistically. The authors followed three steps for conducting the model; first, from available data they constructed the map of landslide inventory, the second step was to identify the direct and indirect physical factors that correlated with the slope instability and getting the thematic maps of affecting landslide parameters, then with using the mean of bivariate statistical they evaluated each factor related to landslides hazard and risk susceptibility, third step was prediction the final map of landslides hazard and risk assessment prediction. The modeling of landslide hazard for this study has a quiet good result. However, the lack of collecting data and missing the landslides time information of previous landslides and a minimum number of factors made the result of this study can not be considered. (Liang and Yang,2008) have been applied another approach by combination the capability of GIS in spatial analysis with AHP to generate and evaluate the multi-index of each factor, the thematic map of landslides susceptibility generated by 5 factors influence in occurring the landslides in the study area, AHP was used for weighting the factors. The verification of this method conducted through collecting true landslide hazard data from field surveys, and it shows a very satisfactory result. However, weighting the factors using AHP has deficiencies, simply because AHP cannot effectively represent the spatial distribution pattern of research results that have been evaluated.

Pradhan *et.al.*,2008) were applied ANN model to study Cameron Highland in Malaysia, which is very heavy rainfall area and faces many landslide events. They used topographical/geological data and satellite images, in addition to GIS capability to analyze 10 landslides parameters. The artificial neural network program and the back-propagation algorithm were applied to calculate the weights between three layers: first between the input layer and the hidden layer, then between the hidden layer and the output layer, using the MATLAB software package. Verification of results of the landslide hazard map was conducted by comparing them with known landslide location data and the accuracy was 83.45%. However, the authors mentioned that they considered precipitation amount as one of ten landslide parameters, but when they used artificial neural network model and weighted factors by back-propagation training method, they

omitted this factor totally and generated landslide hazard map using GIS tools based on the other nine factors only. Hydraulic factors are so important to be considered in studying such area and will improve results accuracy. This is clear in(Abera ,2008) study, he has been studied landslide risk assessment by the collection of historic data of landslides, aerial photographs, and field recognizance to investigate landslide occurrences in addition to GIS. The study strength is by its methodology, it is based on integrating various factors such as topographic, hydrological, land cover, soil types, in addition, it considered three steady state conditions: completely dry, half saturated and fully saturated conditions. The study methods are combined three models:

1- the Slope stability model: based on DEM, land use map and soil map.
2- 2- Hydrological model: based on estimating the soil saturation and pore water pressure.
3- 3- Physical properties of soils. On the other hand, the study does not have any verification to support the result.

(Pradhan and Lee,2009) also applied ANN model in their study as a new promising approach to predict the landslides hazard estimation with using the capability of GIS, the implementation of this approach involves two steps: first, training stage, to adjust the internal weight, and then the classification. Various types of data have been processed for this study; aerial photographs, satellite images, field surveys and geological and topographical and geological dataset. The authors employed ten controlling factors in this study, all the factors generated from a spatial dataset, then with using the GIS tool translated to vector spatial data. The back propagation method has been used for weighting the factors. The trained back propagation applied for calculating the landslides hazard indices. The results verification is performed by comparing the artificial neural network result with landslides location dataset collected from field surveys, the verification of ANN proved the powerful of using this model for analysis of landslide hazard over other methods have applied in last two decades.

(Nithya and Prasanna,2010) studied landslide hazard using satellite data and geographic information systems (GIS). They analyzed the area based on six factors; depth of runoff is one of them. They classified the area according to landslide hazard into four categories; very high, high, moderate and low. They used the experience of "Soil conservation department" to assign the weights for each factor without explaining the implementation way for weighting process. Although they concluded that there is an absence of low runoff in the study area they gave 15% maximum weightage to a depth of runoff. The study has other weaknesses such as the calculation of depth of runoff was from rainfall datum for the year 2004 only without considering the return period of the extreme precipitations; there is nothing mentioned about infiltration factor, and add to that they did not do any verification for the result of this study.

Comprehensive identification of factors was found in(Kawagoe *et.al*.,2010), they studied of landslides hazards over Japan. They used a probabilistic model for their analysis by considering three sets of physical parameters that influence in occurring of landslides: hydraulic, geographical and the geological parameters. Unlike most previous studies, they considered hydraulic gradient as the most influential factor in the occurrence of landslides; and they gave the effect of heavy rainfall and their return period more attention in their study. Their methodology to produced landslide hazard probability maps is to use a multiple logistic regression models and to calculate probability of landslide

occurrence by considering hydraulic gradient, and relief energy. They represent the landslide hazard by using extreme precipitation in 5 years, 30 years, and 100 years return period. The potential possibility of landslides occurrence compared to the actual 374 landslides occurred in 2000, which were detected using aerial photographs over Niigata prefecture then they converted the data into vector-type map and identify two risk conditions "high risk areas" and "low risk areas". Although the comparison shows 88% agreement with the model results but the use of only two zones is insufficient to represent the landslides hazard. To improve the validation accuracy, there should be four or five risk conditions.

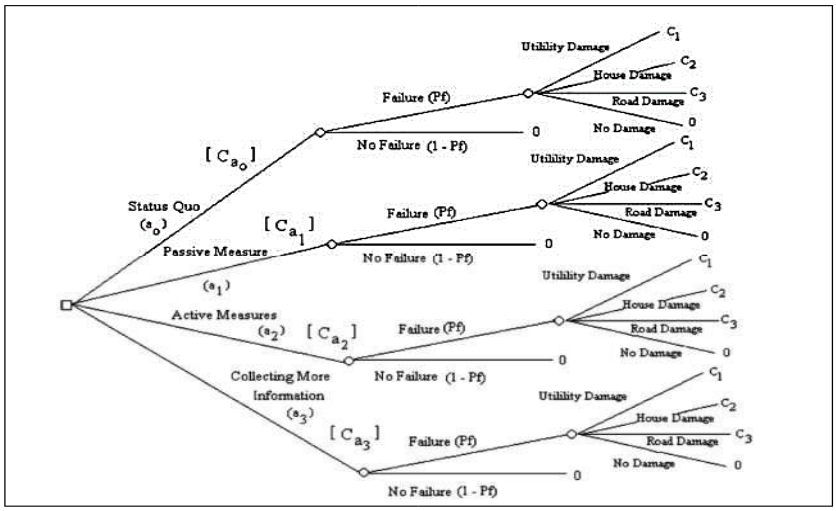
Another method to develop GIS technique (Bilaşco *et.al.*, 2011) which are BPA (Bivariate Probability Analysis) equation. For the study, data obtained by topographic maps, aerial photos and satellite images. The prediction of an analyzed phenomenon using BPA equation conducted by identifying the spatial distribution of each factor and then calculating statistical values for each characteristic interval of the analyzed variable, ranging from negative to positive values. In the study, nine variables were studied and ArcGIS software employed to analyze the influence of each individual variable on the way landslides occur and the results divided into four classes, low, medium, high, and extreme. Finally, validation of the model conducted using the field observations by using GPS (Global Positioning System) for two areas that affected by landslide. The first location fits 97% of the model and the second location fits the model totally. The weakness of the study is that it validate the model by only two locations, and that does not mean the model is really have accuracy of 97% and above.

(Feizizadeh and Blaschke ,2011) combined both of GIS and remote sensing for landslide hazard susceptibility thematic map, through applying fuzzy logic model; they have been involved 7 factors to conduct this study. They gave each factors weight based on using an AHP method. the overall accuracy and the kappa coefficient for this study were 90.2% and 0.88 respectively, it reflects that following this methodology will give high accuracy, however, there is no verification method to follow, in order to test and examine the derived accuracy for this study, the author very satisfied with the weighted values from AHP for each factor that contributed in processing and analyzing in this study, also mapping the landslide hazard with 7 factors even with using powerful approach like fuzzy logic model will not reach high accuracy, we suggest increase the number of factor to at least ten factor to derive satisfactory accuracy.

(LI *et.al*.,2011) proposed a new approach by combination of DT and DARA (Decision Analytical Risk Assessment) to build up the thematic map of landslide hazard susceptibility and risk assessment performing. DARA conducted into five steps, The authors divided the controlling factors into two categories based on landslide susceptibility physical factors and socio economic factors, then integrated in GIS for analyzing, processing and for weighting the factors by linear combination method and involve these factors with its weights in DT to extract the susceptibility landslide hazard susceptibility map, after that they applied the hazard map in ADRA to conduct the landslide risk assessment and management. DT is a powerful approach, however to reaching high accuracy need a high number of factors. This study advises to improve and change some actions and policies that reduce landslide occurring such as improvement of soil fertilizing planting different areas with trees. In this study there is no any verification

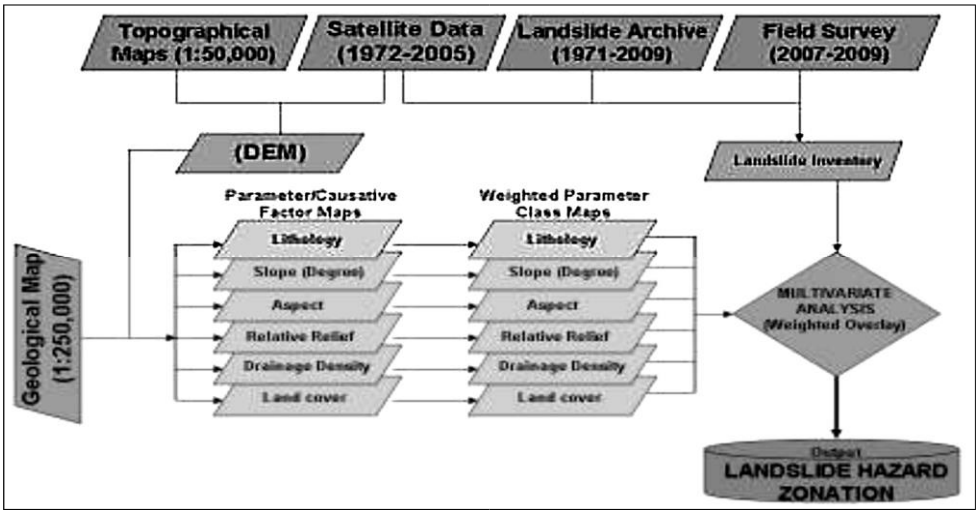
done to support the result of this study, figure (1) shows the rules of DT that have been employed.

Figure 1.Decision Tree rules



(Chandel *et.al.*,2011) suggested a new approach depends on the empirical relationship between the controlling factors that induced or increased the slope instability and landslide. Different kind of data collected for studies such as field surveys, field work, landslides occurrence data and different satellites imageries such as (LANDSAT ETM+, ASTER, and IRS P6). 5 parameters involving into the analyzing and processing, the approach of weighted parametric was used to weight the landslide controlling parameters, then the landslide probability classified into five classes. The result showed high accuracy and the verification of this result conducted by compared the approach result with the result of field survey. The verification reflects a satisfactory accuracy. With using various kinds of data, controlling parameters, field survey datasets and software packages will help to reach a high accuracy level and make the verification easy to perform. Figure (2) demonstrates the methodology that followed for conducting landslide hazard zonation.

Figure 2. Methodology for Landslide Hazard Zonation.



(Pourghasemi *et.al.*,2012) applied a SMCE (spatial multi criteria-evaluation) as a new approach to landslide hazard susceptibility. In this study the authors performed a combination between pairwise comparison and bivariate statistical analysis. Twelve controlling parameters employed for this study. The induced parameters grouped into four categories and then by using Frequency ratio model to score value of each parameters. After that weighting the parameters was the next stage based on its induced on landslide susceptibility, and then standardized the weights levels with using pair-wise comparison. After that SMCE was applied to map the landslides hazard susceptibility, the result was a quiet good and this result verified by field landslide location verification with analysis result, additional, they used the approach of ROC (receiver operating characteristics) for all models of landslide hazard susceptibility. The accuracy of verification showed 76.84%, and according to this result and the number of parameters and the methodology that they followed using the SMCE will give us a promising result for landslide susceptibility, even with around 76.84% accuracy.

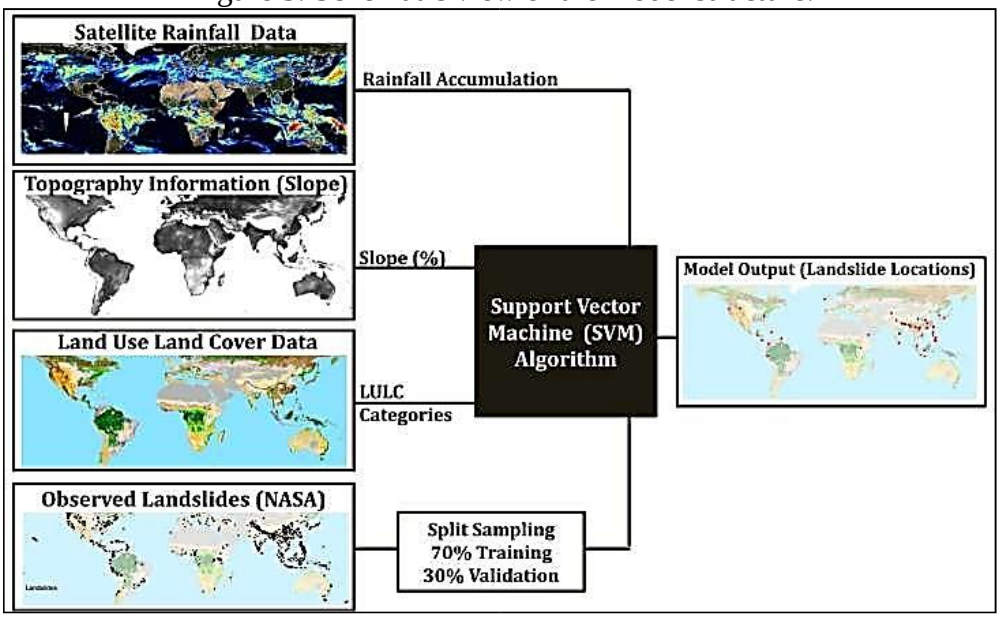
(Pourghasemi *et.al.*,2012) have been applied traditional technique for prediction of Landslide hazard susceptibility using remote sensing data and the capability of GIS. The study conduct through many stages, started from landslide locations identification in the study area from aerial photographs interpretation and field surveys. Twelve controlling factors employed in the next stage that influences in landslide occurrence, after that they used traditional procedure to weight all the factors Evidence Weight Model (this model determines the weight for each factor depends on the presence or absence the landslide within the area). Then estimating the landslide hazard susceptibility based on factors weights. Conducting the result verification of this study done by using the field surveys dataset and also with using the ROC. The accuracy of verification result was showed 71.37%. What we can see in this study from various types of data, analyzing and results verifications techniques have been applied, the accuracy was not quite good for prediction the landslide hazard and risk assessment susceptibility.

(Shahabi et.al.,2012) presented the frequency ratio model for generating the landslide hazard susceptibility map. Data sources were collected from satellite imagery and aerial photographs such as multi-temporal SPOT (Satellite pour l'Observation de la Terre), Landsat ETM+ was used to create the Land use thematic map and also DGPS (Differential Global Positioning System) has been used for investigation for generating the landslide inventory map. Nine factors were used for landslide vulnerability analysis and these factors were weighted using frequency ratio of each factor and computed with previous landslide location. The model is validated using the Relative landslide density index (R-index method). This model is suitable for modeling the landslide hazard susceptibility because the verification was done based on fields survey data.(Pareta and Pareta,2012) also studied landslide hazard in traditional way using GIS techniques, satellite imageries, Survey of India topographical maps, field data, and other informative maps. They classify landslides hazard into four classes: very high, high, moderate, and low, based on data about soil, land use, geological, topographical, and hydrological conditions. In the study, Ranking and Weights of the eight Factors for Landslide calculated based on their estimated significance in causing instability. Although the study area can be considered as heavy rainfall area, they did not account the effect of rainfall value in their analysis. Finally they did not refer how they compared their results with the

existing landslides but they conclude that their results have a close agreement with the existing field.

A global landslides hazard assessment was done by Farahmand and AghaKouchak *et.al.*, 2013) using satellite precipitation data, land-use land cover maps, and topography information. They obtained data and information from NASA (The National Aeronautics and Space Administration) and GSFC (Goddard Space Flight Center), and then they used 70% of the data for numerical model development, and the rest 30% are used for validation and verification. They clearly identified triggering processes and preparatory conditions that cause landslides and they used SVM approach to analysis the data. They used four obtained maps to run their model, they are: Satellite rainfall data, topography information, land use-land cover data, and observed landslides See figure (3) Finally, they validate their model with 100 real historical landslides to find that the average error is about 7 %, while false landslide events were about 2%.

Figure 3. Schematic view of the model structure.

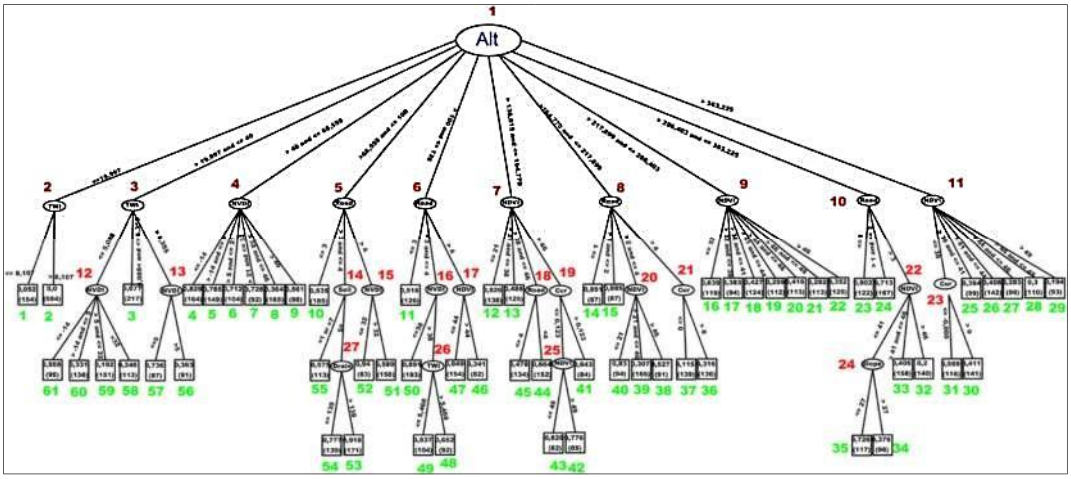


(Pradhan,2013) compared in this study between the predictions performances of three approaches like ANFIS, DT, and SVM for landslide hazard and risk assessment susceptibility mapping. The input factors for the landslide susceptibility were derived from various data sources. Identification landslide locations were conducted by interpreted aerial photographs and field surveys datasets for over 113 landslide locations. Then the research classified the landslides inventory into two categories each part has 50% and he considered the first part of models training phase and the second part is for models validation and models result in accuracy confirm. The final stage was using the derived parameters to extract the landslide hazard and risk assessment susceptibility maps.

There were fifteen landslide prediction maps. The results showed to be quite satisfactory for all the three models (SVM, ANFIS and DT) and also showed the most accurate model is ANFIS, SVM, and DT respectively. For verification the result he compared the models results with the identification landslide locations and also he used the ROC, in this study the researcher applied these methods with same circumstances of

training and testing sites. The way that author followed in conducting this study is a promising technique to follow in prediction of landslide hazard and risk assessment susceptibility, he used field surveys dataset from more than 110 Landslide locations and selecting the controlling parameter based on influencing in landslide occurrence and compared with real landslides locations, using the same training and testing phases for each model will find out which approach has the best performance. Figure (4) shows an example of decision tree model.

Figure 4. An example of decision tree model



4. Conclusions

Over the last two decades, the regional and global landslide hazard and risk susceptibility assessment have become one of the hottest topics in the international and global landslide literature, because the landslide risk assessment is a nonlinear and difficult problem. Different methodologies have been employed, used and discussed for prediction of landslide hazard susceptibility thematic maps. The landslide hazard and risk assessment susceptibility thematic map generate in any study from a combination remote sensing data and the capability of GIS by using various parameters responsible for landslide occurrence, each parameter has importance to probable of landslide activity. In this study, we discussed a different type of algorithms and factors for modeling the prediction of the landslide risk assessment such as SVM, DT, ANFIS, AHP, ANN, probability frequency of landslides occurrence factors model and empirical model. We found from the literature that using ANN algorithm with more than ten factors including hydraulic, geographical and the geological parameters will give high accuracy result especially if the validation performs by field surveys data. For developing the prediction of landslide risk assessment model we should care about the factors that influence directly in inducing the landslide and the procedure for weighting these factors.

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Conflicts of Interest

The authors declare no conflict of interest.

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