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An Application of Artificial Neural Network for Landslide Hazard Mapping, Susceptibility and Early Warning System: A review

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Abstract— Landslides are the most common recurrent and prominent natural disaster in Darjeeling hill region. Darjeeling region has been subjected to a number of extreme landslides especially during monsoon that resulted in a significant loss of life and materials. Thus it required to search a solution towards alertness and development to reduce losses connected with natural disaster landslides. The possibility to develop an early warning system is by applying the modern technology. In modern days, the Artificial Neural Network (ANNs) is widely used in multiple domains. These paper studies the effectiveness and efficiency of using Artificial Neural Network (ANNs) in landslides Mapping, Susceptibility and predictions.

***Keywords*— Landslide, Darjeeling, Artificial Neural Network (ANNs), Alertness, Mapping, Susceptibility, Prediction.**

I. INTRODUCTION

Landslides are one of the major natural hazards in many areas of the world, and globally they cause hundreds of billions of damage, and lakhs of deaths and injuries each year. Landslides are the most common natural hazard in Darjeeling Himalayan region. Therefore, landslide hazard mapping, susceptibility and early warning system are one of the important issues for planning in Darjeeling. The reliability of landslide hazard mapping depends mostly on the availability of quality data and the selection of a robust method.

In many conditions, our primary understanding of soil, rainfall and rock behavior still falls short of being able to predict how the ground will behave. In most cases, expert opinion plays a significant role, and experimental approaches for assessments are widely used for landslides detection and prediction. Landslides are complex processes, mainly because of the many different factors involved in the creation of the occurrence (such as lithology, geological structures, and seismic activities) and geomorphologic features (such as slopes, relative relief, land-use, soils and rainfall). Regardless of different approaches and efforts, no agreement has yet been reached on the techniques and methods for landslide hazard mapping. In different studies, variety of methods have been

implemented and used for landslide susceptibility and risk, they are distribution-based and cannot handle multi-source data that are usually collected from the nature. To overcome these, the desired technique must be able to handle multi-type data and its superiority should increase as the dimensionality and/or non-linearity of the problem increases, which is when traditional techniques often fails to produce accurate approximations. The Artificial Neural Networks emerged as computational modeling tools that have found extensive acceptance in many disciplines for modeling complex real-world problem **(Basheer and Hajmeer, 2000)**. Artificial Neural networks may be defined as structures comprised of densely interconnected adaptive simple processing elements (called artificial neurons or nodes) that are capable of performing massive parallel computations for data processing and knowledge representation. **(Hecht-Nielsen 1990, Schalkoff 1997).**

Artificial Neural Networks has remarkable information processing characteristics of the biological system. It has high parallelism, robustness, nonlinearity, fault and failure tolerance, learning, ability to handle vague and unclear information, and their capability to generalize (Jain et al 1996).
Artificial models possess desirable characteristics such as:

(i) nonlinearity that allow better fit to the data,
(ii) Provides accurate prediction in the presence of uncertain data.
(iii) Parallelism involves fast processing, fault tolerance and hardware failure tolerance.
(iv) It allows the system to update its internal structure in response to changing environment through learning and adaptability.
(v) Enables the application of the model to unlearned data.

II. LITERATURE SURVEY

Research on artificial neural networks has been inspired right from its inception. The key component of this paradigm is the novel structure of the information processing system that is inspired by the way biological nervous systems, such as the brain. It consists of simple computational units, neurons, which are highly interconnected. ANNs have become the focus of much attention, largely because of their wide range of applicability and the ease with which they treat complex problems. ANNs are parallel computational methods comprised of closely interconnected adaptive processing units. These interconnected adaptive processing units are fine-grained parallel implementations of distorted or dynamic systems. The vital quality of these networks is their adaptive environment, where

"learning by example". This makes computational methods very engaging in many application domains where one has tiny or partial understanding of the problem to be solved but where training data set is easily accessible. ANNs are renowned in the area of classification and prediction, where regression model and other related statistical techniques have traditionally been engaged [25].

Types of Learning in Neural Network

An artificial neural network's learning process is a technique, mathematical logic or algorithm which improves the network's performance and training time. Usually, this process is applied over the networks. It is done by updating and adjusting the weights and bias levels of a network when a network is simulated in a specific data environment. A learning process may accept existing weights and biases of the network and will evaluate the expected output and actual result of the network to give new and enhanced values for weights and bias. Depending on the complexity of actual model being simulated, the learning process of the network can be effortless.

The learning process is one of the factors which decide how fast and accurately the artificial neural network can be developed. Depending upon the learning process to develop the networks there are three main learning processes exist which are under mentions:-

i. **Supervised learning:** As the name suggests, supervised learning takes place under the supervision of a teacher. Where the learning process is dependent. Under supervised learning process input as well as desired output is given to the networks. An error sign is generated if there is a difference between the actual output and the targeted output. On the basis of this error sign the weights and bais will be adjusted until the actual output is matched with the targeted one.

ii. **Unsupervised learning:** The learning is done without the supervision of a instructor. The learning process is independent in nature. Under unsupervised learning similar type of data are combined to form clusters. So this kind of learning is usually a clustering technique. Different data patterns of cluster are divided into different classes according to inputs. This type of learning is also known as self organization. During learning when a new input pattern is encountered, it gives response indicating the class to which it belongs. Here, there would be no feedback from the environment as to whether it is correct or incorrect. Hence, the learning itself determine patterns, features from the input and relate the input over the output clusters.

iii. **Reinforcement learning:** The learning is all about making decision consecutively. In other words, the output depends on the state of the current input and the next input depends on the output of the previous input.

III. HISTORICAL BACKGOURND

Neural network simulations appear to be a recent development. However, this field was established before the advent of computers, and has survived at least one major setback and several eras.. The struggle to understand the brain owes much to the pioneering work of Ramón y Cajál (1911), who introduced the idea of neurons as structural constituents of the brain [36]. The first artificial neuron was produced in 1943 by the neurophysiologist Warren McCulloch and the logician Walter Pits. But the technology available at that time did not allow them to do too much [37]. They combined many simple processing units together that could lead to an overall increase in computational power. They suggested many ideas like: a neuron has a threshold level and once that level is reached the neuron fires. It is still the fundamental way in which ANNs operate. The McCulloch and Pitts's network had a fixed set of weights. Hebb (1949) developed the first learning rule, that is if two neurons are active at the same time then the strength between them should be increased. In the 1950 and 60's, many researchers (Block, Minsky, Papert, and Rosenblatt worked on perceptron. The neural network model could be proved to converge to the correct weights, that will solve the problem. The weight adjustment (learning algorithm) used in the perceptron was found more powerful than the learning rules used by Hebb. The perceptron caused great excitement. It was thought to produce programs that could think. Minsky & Papert (1969) showed that perceptron could not learn those functions which are not linearly separable .The neural networks research declined throughout the 1970 and until mid 80's because the perceptron could not learn certain important functions. Neural network regained importance in 1985-86. The researchers, Parker and LeCun discovered a learning algorithm for multi-layer networks called back propagation that could solve problems that were not linearly separable [38][25].

IV. LANDSLIDES SUSCEPTIBILITY AND PREDICTION THROUGH OTHER METHODS

- **Shraban Sarkar *et al*** demonstrated the use of Information Value Method to understand the determinants of the landslide, weighted value of the each factor responsible for landslide was computed by Information Value Method. The result of analysis was checked through success rate – prediction rate curve method

proposed by **Chung and Fabbri (1999)** and by **ROC** curve to assess the performance. Both of them showed high reliability and accuracy of the prediction. But overall no definite correlation was found between slope angle and landslide occurrence but the relationship was positive for slope up to 36°. [3].

- **Emanuele Intrieri *et al*** , have design user-friendly instrument, keeping in mind that most end-users may not have experience with landslide (Early Warning System) EWSs, nor a deep knowledge of them.

The key tasks in the design phase of a landslide EWS are:
(1) Determining the needs and vulnerabilities of the population at risk,
(2) Identifying any impediments to the population taking action if a warning is issued, and
(3) Characterizing the geologic and meteorological setting and conditions that lead to landslide initiation. These conditions are referred to as the geo-indicator.
Many Early Warning Systems (EWSs) suffers from imbalance among their components; for instance some of them may lack in the instrumental/technical element, some in the social/communication aspect or in the understanding of landslide occurrence and their triggers.[7]

- ***Yongbo Wu** et al*, In this study, the fast monitor and real time early warning system for landslide is proposed. This system uses ad-hoc technology to facilitate the repaid layout of the site monitoring network, which improves the robustness of traditional landslides EWSs. Furthermore it builds KF-FFT-SVM early warning model for single landslide through the analysis of the precursor 15 slide character through the deformation data.[1].

- ***Byung-Gon Chae*** et la , this paper focused on the evaluation of the landslide susceptibility using probabilistic approach and physically based method, run out evaluation using volume based model and dynamic model, in situ ground based monitoring techniques, remote sensing techniques for landslide monitoring, and landslide early warning using rainfall and physical thresholds. The classification method was based on the joint application of object-oriented (OOA) and random forests and attained accuracy up to 87% in a supervised approach.

The difficulty in using data-driven methods is the collection of data regarding the landslide distribution and factor maps over large areas.[9].

- ***Govind Singh Bhardwaj*** et al , The sensor is a major device in electronics for measuring physical data from the environment. Sensor can be used for the early prediction system of landslide and it could help in preventing the millions of the losses due to natural hazard. The standard configurations and software are selected on the basis of the utility and application. Some of the key technology and standard elements that are relevant to sensor networks for landslide monitoring detection are as follows: 1. Sensors are chosen according to their functionality viz. Signal processing capability, Compression, forward error correction, encryption, Control/actuation, Clustering and in-network computation etc.

Landslide problem is worldwide but the geographic conditions are different therefore according to the geographic conditions variety of sensors and transmission technology should be adopted [10].

Biswajeet Pradhan and Saro Lee, This paper presents landslide hazard and risk analysis using remote sensing data ,GIS tools and artificial neural network model. Landslide locations were identified in the study area from interpretation of aerial photographs and from field surveys. The artificial neural network proved to be an effective tool for landslide hazard analysis.[5]

- **Chiranjib Nad** ,this study shows that landslide is most common phenomena in Darjeeling hill
  (a) Areas subject to Seismic shaking.
  (b) Mountainous environments with very high relative relief.
  (c) Unscientific mining/land use areas.
  (d) Areas of moderate relief suffering severe land degradation.
  (e) Areas covered with thick sheets of loess.
  (f) Areas with high rainfall and ill drainage system.
  To mitigate landslide hazard effectively new methodologies are required to develop. Besides structural measure some recent measure and non structural measure are also essential for better management of landslide prone hilly terrain of Darjeeling district [17]

- **Priyanka Bhosale et al**, the proposed work is for monitoring the hazard of landslides and by measuring the parameters related to landslides. A complete system for landslide detection within a minimum time in various areas using sensor network. Sensor network will capture data like soil displacement, rainfall,

moisture level in soil etc. and use for prediction of a landslide. The system will take this data for analysis purpose and send an alert if the landslide is detected. The system is also showing a real-time reading of monitoring of the area. Continuous monitoring by the sensor and collected data will be used for predictive analysis. And notify a user about landslide and suggest alternative path based on source and destination.

It has its own limitations such as relatively low amounts of battery power and low memory availability compared to many existing technologies.[19]

- **Zohra A. Shaikh et al**, in this paper wireless sensor network (WSN) technique is used in interim and emergency region for development of real-time monitoring system. This proposed system also explains geophysical sensors for detecting the change in pore pressure and moisture content with warning system developed for landslide detection.

i.Proposed system consist of zigbee modules for remote correspondence and three sensors for information collection are used soil moisture sensor, Humidity sensor and Accelerometer sensor. Warning sensors are installed at remote location which gets activated when sensors values exceed prescribed limit.
ii.LPC 2148 microcontroller collects the information through various sensors and monitors it.
iii.These sensors works in coordination with ARM7 controller to provide the real time data.
To monitor the hazard of landslides and to measure the parameters related to landslides is a difficult task.[13]

- **Abhirup Dikshit et al ,** In this paper, rainfall thresholds have been evaluated using a statistical method which results in the probability of landslide occurrence for single or multiple rainfall parameters leading to slide initiation. The results are expressed in terms of probabilities by analyzing two different variants of Bayes theorem, i.e., 1D and 2D. Probabilistic thresholds were calculated for Kalimpong region of Darjeeling Himalayas using available rainfall and landslide data during the year 2010–2016. The probabilities calculated for landslide occurrence were found to be 0.37for rainfall intensity greater than 10 mm/day. However, the probability for a combination of rainfall intensity of 30 mm/day with duration of 3 days was calculated to be 0.67. The results also

depicted that landslides are related to rainfall event parameters especially with rainfall intensity.

Though various methods have been proposed in the present paper to relate rainfall threshold with landslide occurrence, such approach may not always be helpful to understand the effect and to forecast landslides as it only considers the rainfall which resulted in landslides.[33]

- **Raghunath Pal et al ,** The present study focuses on an overall scenario of the landslide occurrences of the Tista basin in Darjeeling in the context of the historical evidence

1. The Tista basin is one of the most vulnerable river basins in the Himalayan region from the perspective of the erosive character.
2. The prominent causes of landslides in the basin are torrential rainfall, fragile geology, earthquake and deforestation.

3. It is almost impossible to prevent the natural causes of landslides but the human induced factors viz. deforestation, agricultural expansion, building and road construction, embankment, bridge and barrage construction etc. can be controlled to reduce the severity on the basin dynamics.

Overall no definite correlation was found between the factors causing the landslides in the Tista basin.[24]

V. LANDSLIDES SUSCEPTIBILITY AND PREDICTION USING ARTIFICIAL NEURAL NETWORK

- **Amit Chawla** *et al* , this study presents a methodology for the generation of landslide susceptibility mapping using *Genetic Programming (GP)* which is an evolutionary computing technique that is used to solve a variety of complex problems for the part of the Darjeeling district, Eastern Himalaya, in India.
  Despite advances in science and technology, landslides continue to result in economic, human, and environmental losses worldwide. In this study, more than 15% of total land area in India is considered to be affected by landslides.[8].

- **Emmanuel Léonard and hou-Hao Chiang**, this study aims to perform landslide susceptibility analysis for the Yushan National Park (YNP) in central Taiwan based on an Artificial Neural Network (ANN) Model using Remote Sensing data and Geographical Information System (GIS).

The back-propagation training algorithm is used. It is a learning rule algorithm of multilayered artificial neural networks, which consists of an input layer, hidden layers, and an output layer. The hidden and output layer neurons process their inputs by multiplying each of their inputs by corresponding weights, summing the product, processing the sum using a nonlinear transfer function to produce a result.

The probabilities of landslide occurrence determined by the ANN model were applied to create the landslide susceptibility map using GIS tools [6].

- **L.D.C.S. Subhashini, H.L. Premaratne** ,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. This research indicates that the proposed mechanism could be used as a strong decision support system to predict landslides efficiently and effectively. Based on this research twelve factors were initially identified as the most relevant to influence landslides.[2]
- **Biswajeet Pradhan and Saro Lee**, This paper presents landslide susceptibility analysis in the Klang Valley area Malaysia, using back-propagation artificial neural network model. The landuse of the study area consists mainly of peat-swamp forest, plantation forest, inland forest, scrub, grassland and ex-mining area.ANN results are better than the earlier method.

The ANN modeling approach, combined with the use of remote sensing and GIS spatial data, yields a reasonable accuracy for the landslide prediction. However, in order to obtain higher prediction accuracy it is recommended to use a suitable dataset of landslide data.[4]

- **Jagabandhu Roy and Sunil Saha**, The present work, intends to identify the landslide susceptibility zones for Darjeeling, India, using the ensembles of important knowledge driven statistical technique i.e. fuzzy logic with Landslide Numerical Risk Factor (LNRF) and Analytical Hierarchical Process (AHP). Moreover, the Fuzzy-LNRF model is promising and sufficient to be advised as a method to prepare landslide susceptibility map at regional scale.

i. Landslide inventory map has been prepared based on this landslide prone zone.

ii.Landslide susceptibility maps were prepared based on the Fuzzy- Landslide Numerical Risk Factor (LNRF) and Fuzzy- analytic hierarchy process (AHP) methods in a GIS environment.
iii.The landslide maps of both models have been validated through ROC curve and RMSE.[14]

- **I.A.Basheer,M.Hajmeer**, Artificial neural networks are relatively new computational tools that have found extensive utilization in solving many complex real-world problems. Artificial Neural Networks are computational modeling tools that have recently emerged and found extensive acceptance in many disciplines for modeling complex real-world problems. The remarkable information processing capabilities of ANNs and their ability to learn from examples make them efficient problem-solving paradigms. ANNs' success depends on both the quality and quantity of the data. Lack of clear rules or fixed guidelines for optimal ANN architecture design.

A lack of physical concepts and relations, and the inability to explain in a comprehensible form the process through which a given decision was made by the ANN.

- **Mitali S Mhatre et al** , The input technique Artificial Neural Network (ANN) is used to improve prediction accuracy of the model with less dependency on experimental data. The basic steps used in MATLAB are reported along with different ANN trainings. The basic steps of ANN used in MATLAB
a. Collection of input-output dataset
b. Pre-processing of input-output dataset
c. Neural network design and training
d. Performance evaluation of the neural network.
Proper care must be taken while applying the ANN to these processes and needs training to operate. [27].

- **Rani Pagariya , Mahip Bartere,** in the study the key element of this paradigm is the novel structure of the information processing system. An ANN is a computational structure that is inspired by observed process in natural networks of biological neurons in the brain. Basic methods how neuron learn, so it get easy for beginner to learn about ANNs. The back propagation algorithm (Rumelhart and McClelland, 1986) is used in layered feed-forward ANNs. This means that the artificial neurons are organized in layers, and send their signals "forward", and

the errors are propagated backwards. The massively parallel nature of a neural network makes it potentially fast for the computation of certain tasks.[25].

- **Er.Parveen Kumar1, Er.Pooja Sharma**, In ANN most of the learning rules are used to develop models of processes, while adopting the network to the changing environment and discovering useful knowledge. In ANN computations can be carried out in parallel. Neural networks teach themselves the patterns in the data freeing the analyst for more interesting work. The neural networks can build models that are more complex in the structure of the data in significantly less time. By studying Artificial Neural Network we had concluded that as the technology is increasing the need of Artificial Intelligence is increasing because of parallel processing, because by using parallel processing we can do more than one task at a time. But there is no single standardized paradigm for Neural Networks development. And the output quality of an ANN can be unpredictable.[29].
- **Joselin.J et al**, the study shows that the ANNs are widely applied in research because they can model highly non-linear systems in which the relationship among the variables is unknown or very compound.

The computing world has a lot to gain or benefits from neural networks approaches. Their ability to learn by example makes them very flexible and powerful. Furthermore there is no need to devise an algorithm in order to perform a specific task i.e. there is no need to understand the internal mechanisms of that task.[30].

- **Ms. Sonali. B. Maind ,** This paper gives overview of Artificial Neural Network, working & training of ANN. It also explains the application and advantages of ANN. They modeled a simple neural network with electrical circuits. Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. The system is developed through learning rather than programming.[28]

VI. ARCHITECTURE OF ARTITIFICIAL NEURAL NETWORK(ANN)

Neural Networks are complex structures made of artificial neurons that can take in multiple inputs to produce a single output. This is the primary job of a Neural Network– to transform input into a meaningful output. Usually, a Neural Network consists of an input and output layer with one or multiple hidden layers within.

In a Neural Network, all the neurons influence each other, and hence, they are all connected. The network can acknowledge and observe every aspect of the dataset at hand and how the different parts of data may or may not relate to each other. This is how Neural Networks are capable of finding extremely complex patterns in vast volumes of data.

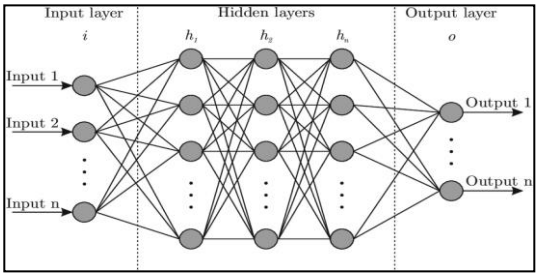

Figure 1: Architecture of Artificial Neural Network

There are several types of architecture of ANN. However, the two most widely used ANN are as follows:

a. **Feed-forward ANNs** allow signals to travel one way only, from input to output. There is no feedback or loops. The output of any layer does not affect that same layer in such networks. Feed forward neural networks are straight forward networks that associate inputs with outputs. They have fixed inputs and outputs. They are mostly used in pattern generation, pattern recognition and classification.

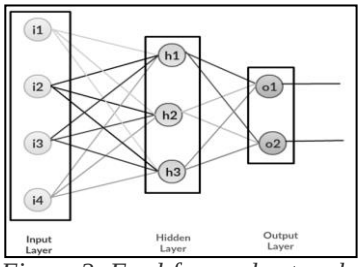

Figure 2: Feed-forward networks

b. **Feedback Neural Network,** Signals can travel in both the directions in Feedback neural networks. Feedback neural networks are very powerful and can get very complicated. Feedback neural networks are dynamic. The 'state' in such network keeps changing until they reach an equilibrium point. They remain at the equilibrium point until the input changes and a new equilibrium needs to be found. Feedback neural network architecture is also referred to as interactive or recurrent, although the latter term is often used to denote feedback connections in single-layer organisations. Feedback loops are allowed in such networks. They are used in content addressable memories.

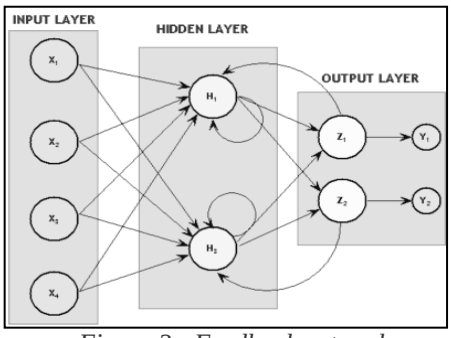

Figure 3 : Feedback networks.

In a Neural Network, the learning (or training) process is initiated by dividing the data into three different sets:

- **a. Training dataset –** This dataset allows the Neural Network to understand the weights between nodes.
- **b. Validation dataset –** This dataset is used for fine-tuning the performance of the Neural Network.
- **c. Test dataset –** This dataset is used to determine the accuracy and margin of error of the Neural Network.

VII. BENEFITS OF ARTITIFICIAL NEURAL NETWORK

a. Information is stored on the entire network. The disappearance of a few pieces of information in one place does not prevent the network from functioning.

b. After ANN training is complete, the data may produce output even with incomplete information.

c. The ANN makes the networks fault tolerant even if corruption of one or more cells does not prevent it from generating output

d. In order for ANN to be able to learn, it is necessary to determine the examples and to teach the network according to the desired output by showing these examples to the network.

e. Artificial neural networks learn events and make decisions by commenting on similar events.

f. Artificial neural networks have complex computational strength that can perform more than one job at the same time.

VIII. CHALLENGES AND SCOPES

The future of Artificial Neural Networks and its applications will help to understand the importance and essentiality of their role in mapping and susceptibility of landslide areas. All current Artificial Neural Networks (ANN) technologies will likely to improve in the future. Everything from handwriting, speech recognition, forecasting thunderstorm to stock market prediction will become more sophisticated as researchers have develop better training methods and network architectures. Artificial Neural Networks have more scope in days to come allowing

a. Robots to see, feel, and predict the world around them.
b. Improved various prediction systems.
c. Handwritten documents to be transformed into formatted word documents.
d. To understanding the trend of the data compiled by the Human Genome Project.
e. Self-diagnosis of medical problems
f. Speech recognition
g. Face recognition and detection system.[39] [40]

IX. CONCLUSION

In this study, landslide mapping and susceptibility was studied by an Artificial Neural Network (ANN) approach. Artificial Neural Network (ANN) is an emerging area that showed some promising result in the field of prediction with high accuracy. It is still an open domain waiting to get implemented in various other predication systems. A comprehensive literature review is presented to compare the performance of artificial neural network and its implementations. The methods like ROC curve, PSO (Particle Swarm Optimization), SVM (Support Vector Machine), Genetic Programming, Random Forest, GIS and Statistical Methods are the most commonly used approaches which are still not sufficient to predict the natural hazard accurately. On the other hand Artificial Neural Network (ANN) is able to distinguish the landslide areas more precisely, with a proper network structure and adequate training iterations, the ANN tend to detect the exact points of landslides with a very small portion of false-positive predictions.

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