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COMPARATIVE ASSESSMENT OF DEEP LEARNING AND MACHINE LEARNING MODELS IN SHALLOW LANDSLIDE SUSCEPTIBILITY ZONATION

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Introduction

Landslides are ubiquitous, recurrent, and catastrophic natural phenomena that lead to many fatalities, destruction of vegetation cover, and also drastic financial losses. Accordingly, the correct identification of landslide-prone sites is of considerable significance in terms of disaster management and mitigation studies. In this context, landslide susceptibility maps represent significant information in taking the necessary preventive measures for policy-maker individuals and public institutions (Kavzoglu et al., 2014). However, the dynamic, site-specific, and inconsistent nature of landslides complicates identifying the main factors that predispose their occurrence, and thus, the production of such maps remains a challenging task. To achieve these challenges, machine learning (ML) algorithms have recently captured the utmost attention from the scientific community owing to their robustness compared to traditional statistical methods (e.g. frequency ratio, analytical hierarchy process). Even though such algorithms have obtained success to a certain level in some cases, they might fail to reach satisfactory or superior achievement. Besides, several previous researches reported that they may encounter some obstacles in processing and estimating large data set as ML algorithms were developed based on multiple assumptions (L'Heureux et al., 2017). Aside from ML algorithms, a novel and evolving paradigm, namely deep learning (DL), has been introduced to overcome the aforementioned limitations. DL has been intensively employed as a significant method involving multi-layered structures for analyzing and processing big data. These multi-layer structures process the non-linear information and enable to interrelate the connections between the previous and following layers. In recent years, Long Short-Term Memory (LSTM), one of the DL models, has been used especially in prediction applications containing sequential data (Mubashar et al., 2021).

In this present work, a comparative analysis was carried out to generate more reliable landslide susceptibility maps for the Trabzon province of Turkey. For this purpose, the random forest (RF), which is a well-known benchmark ML algorithm, and LSTM were considered. Based on the main topographical, geological, and environmental characteristics of the study area, 12 landslide predisposing factors were utilized. Two accuracy assessment metrics including overall accuracy (OA) and area under curve (AUC) score were calculated to evaluate and compare predictive performances of algorithms. Apart from the performance evaluation measures, the statistical test was utilized for investigating the statistical significance of the difference in the predictive accuracy of algorithms.

Materials and Methods

In the current study, 12 landslide conditioning factors namely aspect, elevation, lithology, normalized difference vegetation index (NDVI), distance to rivers, road density, distance to roads, slope, slope length, topographic position index (TPI), topographic ruggedness index (TRI), topographic wetness index (TWI) were all considered to model the landslide susceptibility of Trabzon province, located in the northeast part of Turkey. The area of interest is geographically located 39° 15′ and 40° 15′ longitudes and 41° 08′ and 40° 30′ latitudes and it covers a total area of 4,664 km2. In this region, specifically in the Trabzon province, landslides are a ubiquitous and rising concern for the residents due to the climatic circumstances physiographic characteristics, and hilly geomorphological features. For all these above-mentioned reasons, the province of Trabzon was considered as the area of interest in the study.

To predict landslide susceptibility, a ML technique (i.e. RF) and a DL algorithm (i.e. LSTM) were employed. Introduced by Breiman (2001), RF is an ensemble learning technique that is applied by combining many decision trees. To train the model, RF utilizes the statistical bootstrapping technique. Each tree in the forest is trained using about 2/3 of the samples and the remaining samples are used to estimate the performances of the tree model. Eventually, the majority voting rule is considered to estimate class labels of unknown instances (Kavzoglu, 2017). On the other hand, LSTM Neural Networks (NN) is a variant of the Recurrent Neural Network (RNN). However, the conventional RNN causes the problem of vanishing or exploding gradient. Therefore, the LSTM model was improved to overcome these limitations, also reducing the dependence of the model on the training data (Sherstinsky, 2020). The model of LSTM contains input, hidden, and output layers. There are units of hidden layers that follow each other in the model, in which gates (forget, input and output) and cell states perform the learning process. The forget gate decides which data to forget or not, additionally, the cell states are responsible for carrying the information inside the cell. The input gate uses an activation function such as Sigmoid which updates the cell state, while the output gate is responsible for transmitting the information from the cell state to the next unit (Hochreiter and Schmidhuber, 1997).

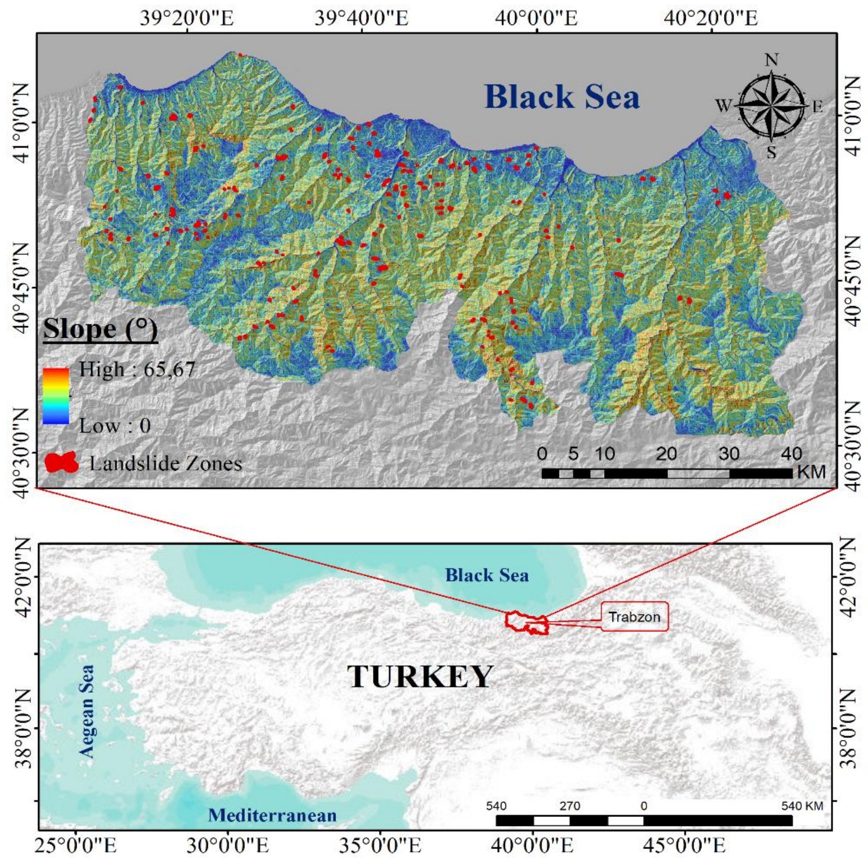

Figure 1 Location of the study area and landslide zones

Results and Discussion

The predictive performances of two algorithms (i.e., RF and LSTM) were evaluated using well-known accuracy metrics. Results indicated that the LSTM outperformed the RF in terms of both measures. OA results showed that the LSTM with 88.72% had a higher score compared to the RF algorithm (84.62%). Another measure intensively utilized in landslide susceptibility studies is the AUC value. The results of the AUC analysis revealed that the LSTM with an AUC score of 94.78% had a higher discrimination capability compared to the RF (93.80%). According to the Wilcoxon signed-rank test results, the estimated statistical test value between RF and LSTM models was found to be 0.0001. As a result, it can be said that the predictive performance of the LSTM algorithm is statistically different from the RF model.

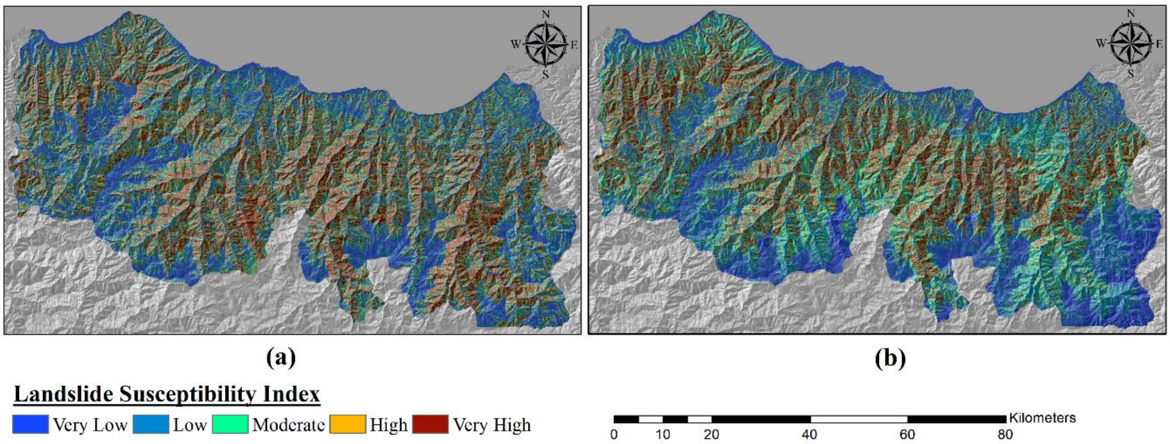

Figure 2 Landslide susceptibility maps produced by (a) LSTM and (b) RF

Conclusion

According to the indication of the study, several important inferences can be drawn about the suitability and effectiveness of the DL strategy for landslide susceptibility mapping procedure compared to the RF. First, the LSTM outperformed the RF algorithm by approximately 4% in terms of OA. Secondly, this finding related to the accuracy evaluation criteria was also statistically confirmed by Wilcoxon signed-rank test. In a nutshell, landslide susceptibility maps produced with DL algorithms provide essential insights to decision-makers in terms of the application of more effective disaster management procedures.

Keywords: *Landslide Susceptibility, Deep Learning, Machine Learning, Long Short-Term Memory, Random Forest*

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