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Spatial interpolation and radiological mapping of ambient gamma dose rate by using artificial neural networks and fuzzy logic methods

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ABSTRACT

The aim of this study was to determine spatial risk dispersion of ambient gamma dose rate (AGDR) by using both artificial neural network (ANN) and fuzzy logic (FL) methods, compare the performances of methods, make dose estimations for intermediate stations with no previous measurements and create dose rate risk maps of the study area. In order to determine the dose distribution by using artificial neural networks, two main networks and five different network structures were used; feed forward ANN; Multi-layer perceptron (MLP), Radial basis functional neural network (RBFNN), Quantile regression neural network (QRNN) and recurrent ANN; Jordan networks (JN), Elman networks (EN). In the evaluation of estimation performance obtained for the test data, all models appear to give similar results. According to the cross-validation results obtained for explaining AGDR distribution, Pearson's *r* coefficients were calculated as 0.94, 0.91, 0.89, 0.91, 0.91 and 0.92 and RMSE values were calculated as 34.78, 43.28, 63.92, 44.86, 46.77 and 37.92 for MLP, RBFNN, QRNN, JN, EN and FL, respectively. In addition, spatial risk maps showing distributions of AGDR of the study area were created by all models and results were compared with geological, topological and soil structure.

1. Introduction

Gamma rays are an ionizing radiation and cause damage in the cell structure and DNA (Donà et al., 2013; Vilenchik and Knudson, 2000). The amount of energy absorbed per unit body tissue of gamma rays is defined as radiation dose and the amount of radiation dose absorbed by the body per unit time is the dose rate. People are exposed to gamma dose rate in their living environments over their life time (UNSCEAR, 2000). Determining and monitoring gamma dose rate, caused by cosmic rays as well as both natural and artificial radionuclides, is very important in terms of public health (ICRP, 1991). In recent years, many studies were conducted to determine the gamma dose rates in many countries (Hososhima and Kaneyasu, 2015; Jibiri, 2001; Karahan and Bayulken, 2000; Karunakara et al., 2014; Kobya et al., 2015; Lespukh et al., 2013; Ramli et al., 2009; Reistad et al., 2008; Sanusi et al., 2014). However, these studies provide gamma dose rate values for measurement stations only. This is one of the biggest problems in determining the distribution of radiological risk areas as well as mapping of these areas. In studies conducted in recent years, this problem was partly solved by geostatistical methods (Cafaro et al., 2014; Hiemstra et al., 2009; Pebesma, 2005; Savelieva, 2005; Szegvary et al., 2007; Warnery et al., 2015; Yeşilkanat et al., 2015). However, the linear structure of predictive function and smoothing outlier measurements in order to get average error values close to zero in interpolation calculations (Diggle and Riberio, 2007; Webster and Oliver, 2007) revealed the necessity of investigating other alternative methods to determine radiological distributions. In recent years, researchers have used artificial neural networks (ANN) and Fuzzy logic (FL) approaches in the estimation of spatial interpolation (Akumu et al., 2015; Celio et al., 2014; Kurt et al., 2008; Ocampo-Duque et al., 2013; Suganthi et al., 2015; Wang et al., 2015).

A limited number of studies have been conducted to evaluate spatial distributions of environmental radioactivity by using an artificial neural networks (ANN) method (Dutta et al., 2005; Rigol-Sanchez, 2005; Timonin and Savelieva, 2005). However, changing input parameters depending on only latitude and longitude

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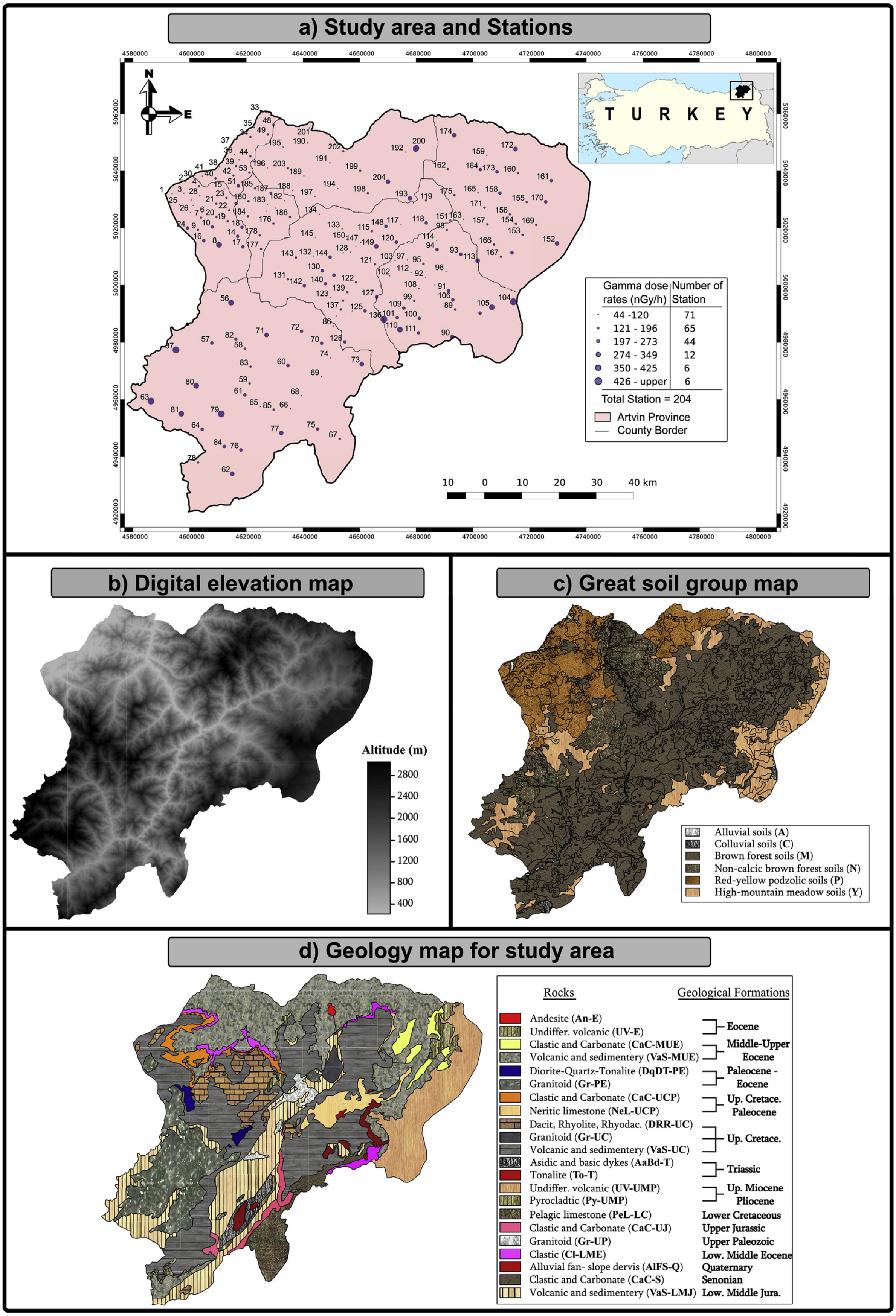

Fig. 1. a) Study area and sampling stations, b) Digital elevation map created for the study area (USGS, 2013), c) Great soil groups map of the study area (Yavuz Özalp et al., 2013), d) Rock structure and geological map of the study area (Modified from geological map of Turkey with MTA 1/500000 scale) (MTA, 2002).