Artificial neural networks aided annual rainfall erosivity factor values calculation in Poland

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Abstract: Calculation and analysis of annual R-factor local values for 103 stations in Poland were the main aims of this study. Calculations were made by means of single hidden layer perceptron artificial neural network on the base of monthly precipitation totals from years: 1961-1980. For most of the analyzed stations calculated average annual R-factor values were low or moderate, at the range from 50 to 80 $MJ \cdot ha^{-1} \cdot cm \cdot h^{-1}$. A strong relation between calculated average annual factor values and station elevation above see level was observed. Because of this, geostatistical algorithms incorporating elevation information should be used for further updating the isoerodents map of Poland.

1 Introduction

Development of new updated isoerodents map of Poland represents one of the most important goals of the Polish State Committee for Scientific Research Project 3P04G08425: “Geostatistical methods application for environmental monitoring data processing.” Until now, rainfall erosivity R-factor proposed by [WS78] is considered as a useful tool for regional climatic condition description with respect to soil erosion by water in Polish soil conservation practice. R-factor is applied both for soil erosion hazard mapping and soil erosion by water modeling since USLE and RUSLE type models are still in practical use in Poland [Li03]. New generation of physically based soil erosion prediction models like WEPP (Water Erosion Prediction Project) [FN95] was not introduced into the practice in the country, mainly due to their very elevated input data needs. At the same time there is still lack of precise isoerodents map of Poland. First of all, it results from the lack of a nationwide solid R-factor database. Local factor values were calculated according to rules developed by [WS78] and on the base of rainfall registrations from constant recording raingauges for only about 10 stations in Poland. Currently, the progress of factor calculation for new locations is almost completely blocked by the lack of financial sources for rainfall intensity data series purchase from the Institute of Meteorology and Water Management (IMWM) and for necessary labor consuming data processing.

The first isoerodents map of Poland was developed by [Lo85] on the base of monthly precipitation totals and by means of simple Fournier Index (FI) method application in 1985. Current studies have shown however weak capability of the simple FI method for local R-factor estimation under Polish conditions [Li04a]. It should also be mentioned that the accessibility to Lorenc's map was strongly limited for a long time since it was published as internal IMWM report only [Lo85]. The map was introduced for a wider audience after 10 years by [JJ95]. In 2005, preliminary results of rainfall erosivity mapping for Poland were presented by [LS05]. The new approximated isoerodents map of Poland was developed on the base of R-factor values estimated by [Li04b] for 67 stations by means of double hidden layer perceptron artificial neural network on the base of average monthly precipitation totals from years 1951-1970. Geographical Information Systems (GIS) techniques and statistical methods (regression analysis associated with statistical hypothesis testing) were introduced in practice for average annual R-factor spatial distribution estimation for the area of Poland. Authors proved that digital elevation model (DEM) (GEOTOPO30 of 1 km spatial resolution, rectified into 1992 arrangement) should be used to aid mapping of rainfall erosivity [LS05]. At the same time the need for a higher station density especially for mountainous areas was recognized.

Elaboration of an improved spatial database of average annual R-factors for Poland was the main aim of this study. It was planned not only to enhance the quantity of analyzed stations, but also to introduce the more precise method of factor estimation developed by [Li04a] in practice. Calculated R-factors values analysis was the second study aim.

2 Material and method

A database consisted of monthly precipitation totals from years 1961-1980 for a total number of 103 gauging stations in Poland was prepared for the study realization. Stations were selected to cover the whole country with the quite smooth distribution. A higher density of stations was taken into consideration for mountainous areas in Southern Poland since the terrain orography strongly effects local precipitation characteristics.

Calculations were made by means of previously developed and trained single hidden layer perceptron artificial neural network of the following architecture: MLP: 12:12-7-1:1. It was perceptron network with a single hidden layer having 7 neurons, input layer of 12 neurons and single neuron output layer. Linear, hyperbolic and logistic functions were used as activation functions for neurons of input, hidden and output layers, respectively. Network was designed and trained with the use of STATISTICA 6,0 software and its Neural Networks application. [Li04a].

For all stations and analysed years, monthly precipitation totals in mm were provided as inputs for the network. Annual rainfall R-factor values in EU (1EU=1 $MJ \cdot ha^{-1} \cdot cm \cdot h^{-1}$) were obtained as the outcome of the network calculations.

3 Results and discussion

As a result of calculations values of annual R-factor for 2060 station-years were obtained. For every single station, average annual R-factor values were calculated and years with the highest and the lowest factor values were identified. Results of above mentioned operations are presented in figure 1. The lowest annual rainfall erosivity factor was observed for Kostrzyn nad Odra station located on an elevation of 15 m a.s.l., with only 3,9 EU in year 1976. The highest annual factor (292,9 EU) was observed in year 1978 for the high mountain top station – Kasprowy Wierch, having an elevation of 1991 m a.s.l. Also the highest calculated average annual R-factor (186,4 EU) was for Kasprowy Wierch station. In contrary to this, the lowest average annual rainfall erosivity value (37,0 EU) was obtained for Swinoujscie station located by the see on an elevation of only 2 m a.s.l.

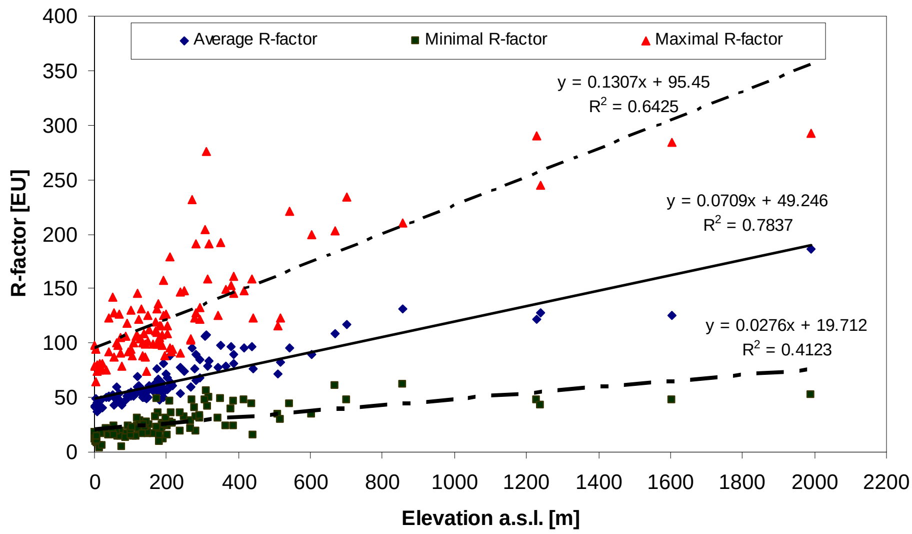

Figure 1: Calculated minimal, maximal and average annual R-factor values versus station elevation above see level

As can be seen from the figure 1, minimal, maximal and average annual R-factors were in strong relation to station elevation above sea level. Correlation coefficients calculated for the linear regressions of parameters in question were equal to: $r_{min.}$=0,642; $r_{max.}$=0,802; $r_{ave.}$=0,885, respectively. Especially the high correlation coefficient of average annual values, suggests the need of geostatistical algorithms like cokriging and a digital elevation model incorporation for future mapping of annual erosivity values in Poland, as it was made previously by Goovaerts [Go99] for Algarve region in Portugal.

Moreover, as can be observed on figure 1 most of analysed stations were characterized by low or moderate average annual R-factors, usually at the range from 50 to 80 EU. Elevated, exceeding 100 EU, average annual factor values were observed for mountainous stations, whereas low annual factors were typical for lowland stations. This was in a good agreement with previous studies of [Li04b] and [LS05].

4 Conclusions

As a result of the study a database of average annual R-factor values for 103 stations in Poland was developed. This database can be used in the future for the elaboration of a new updated isoerodents map of Poland. A strong relation, almost of linear form, between calculated average annual factor values and station elevation above see level was noticed. Generally, higher values of R-factor were observed for stations located in the mountains of southern territory than in case of lowland stations of central and northern Poland. Because of this geostatistical algorithms incorporating elevation information should be used for final isoerodents mapping

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