USE OF ARTIFICIAL NEURAL NETWORKS AS A RUNOFF-EROSION MODEL APPLIED TO A SEMI-ARID REGION OF BRAZIL

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1. INTRODUCTION

The semiarid portion of the Brazilian northeast is characterized by rainy periods concentrated in few months of the year. However, these events have great intensity and short duration. These conditions cause fast runoff and great sediment production, which can be intensified by anthropic actions such as agriculture, cattle-breeding and deforestation of the native vegetation. The eroded materials are carried to lower regions of the watershed, reducing storage volume of water bodies as well as harming the water quality.

In order to find a method for supporting and recouping these areas, hydro-sedimentological processes must be investigated. This work aims at proposing an Artificial Neural Network (ANN) model for predicting and quantifying the sediment discharge as a function of the runoff and climatologic data. ANNs are capable of extracting and detecting the most complex nonlinear trends among the involved variables[1].

2. CASE STUDY AND DATA COLLECTION

The case study consists of an experimental plot inside the micro-watershed of São João do Cariri, which is located in the semi-arid portion of Paraíba State, Brazil. This area holds a dry climate, ground with fine layers over rocks, characteristic vegetation of the region (semi-arid of Brazil) and surface with variations from 450m up to 550m above sea-level. The annual temperature and precipitation are around 25°C and from 370 mm to 600 mm, respectively. The precipitation has an irregular distribution with eight months of dry season and a short season with concentrated and intense rainfall.

The experimental erosion plot was installed in the northeast of the micro-watershed and has an area of 100 m² (4.5m x 22.2m). The plot has a slope of approximately 3.4%. The erosion area is often deforested following the Wischmeier[2] norms. After each rainfall event, the runoff and soil erosion produced are measured from the experimental plot. Figure 1 shows the experimental plot of this work.

3. ANN-BASED RUNOFF-EROSION MODEL

The model scheme is a multilayer feed-forward ANN formed by three layers. Figure 2 illustrates the topology of the ANN model. The input layer is formed by eight nodes (neurons), which are the rainfall (*R*), rainfall duration (*D*), runoff (*Ro*), minimum and maximum temperature in the day of the event *n* (*Tmin* and *Tmax*), irradiation in the day of the event *n* (*I*), and number and mean temperature of previous days without rainfall (*Dwr* and *Tmean*). The number of nodes in the hidden layer is determined applying a trial-and-error procedure. The best training results were achieved with seven nodes. The sediment discharge produced is the single node of the output layer.

For neural networks, not only the way neurons are implemented but also how their interconnections (topology) are made is important. In this study the network topology is constrained to be feed-forward, i.e., the connections are allowed from the input layer to the hidden layer and from the hidden layer to the output layer. Figure 2 illustrates the network topology of this study.

Continuous and differential functions are necessary for relating inputs and outputs of the artificial neural networks.

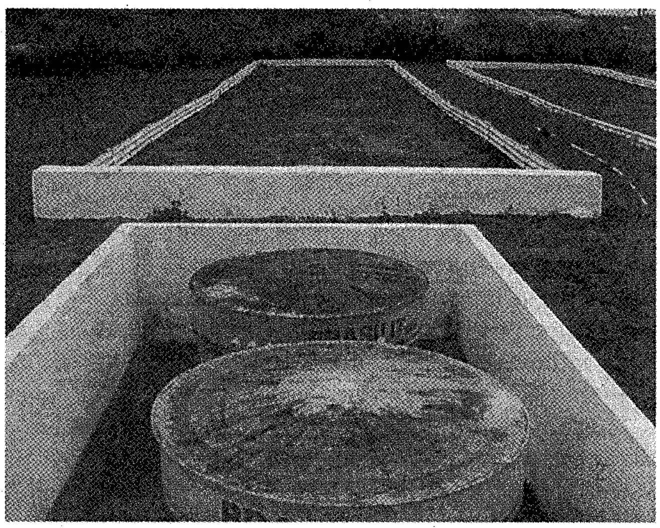

Figure 1 Experimental erosion plot.

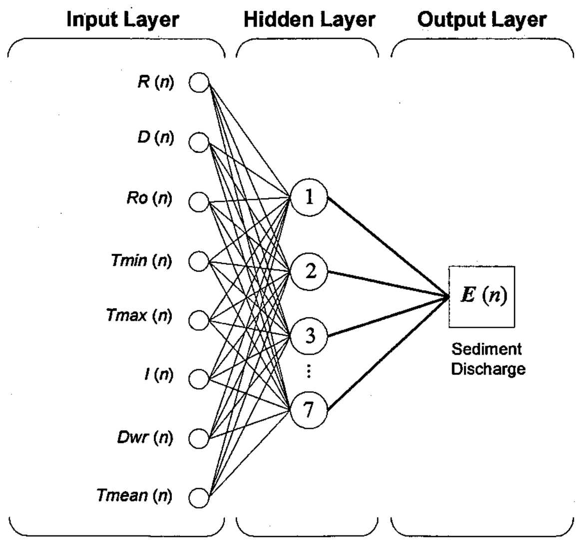

Figure 2 Topology of the ANN.

According to Haykin[3] the sigmoid function is a good activation function for each neuron due to its generally accepted behavior. The tan-sigmoid function is chosen as the activation function for the hidden neurons. For the output layer neuron, a linear activation function is used.

The original data (input and targets) are conveniently scaled before the ANN training[4]. The training is performed by a back-propagation algorithm which has been successfully applied to water resources systems. In this approach, the gradient descend method is used for the back-propagation. A detailed explanation of the gradient descend method is provided by Haykin[3]. The training process stops by means of the *Early Stopping Method*[4].

4. RESULTS

An ANN-based runoff-erosion model was used for predicting the sediment discharge as a function of variables such as runoff and climatologic data. The total of 61 rainfall events, occurred between the years of 1999 and 2002, were used for the model calibration and test.

Since the model calibration used the *Early Stopping Method*, the training data set was divided in two subsets: the first (34 events) was used for the ANN model training and the second (15 events) for validation to specify when to stop the network training. The tests were carried out over the other 12 events.

Figure 3 illustrates the scatter graph of ANN and observed sediment discharges for the training data set. This graph shows the good correlation reached by the ANN-based runoff-erosion model.

The prediction tests are presented in Figures 4 and 5. Figure 4 shows the comparison between ANN sediment discharges and observed results. Figure 5 presents the scatter graph of ANN and observed sediment discharges for the test data set.

Examinations of Figures 4 and 5 show us that the ANN-based runoff-erosion model produced results very similar to those from the observed data. This information indicates that the ANNs' capabilities in extracting complex trends may be suitable for developing runoff-erosion models for semi-arid areas where historical data is available.

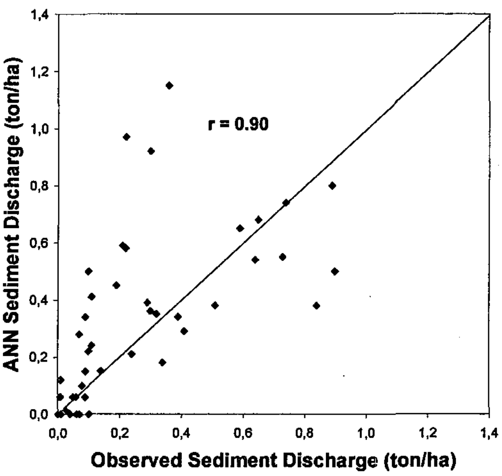

Figure 3 Scatter graph of ANN and observed sediment discharges for the training data set.

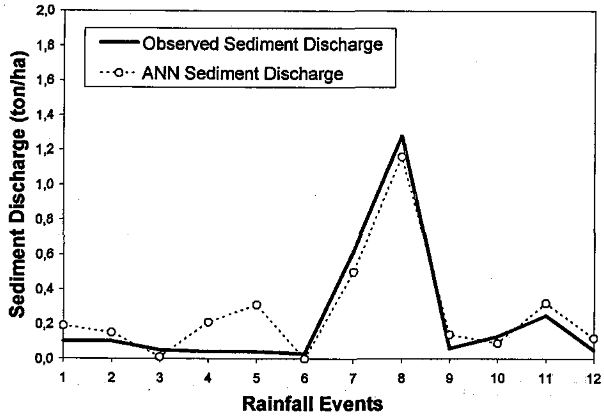

Figure 4 Results for the events of the test data set.

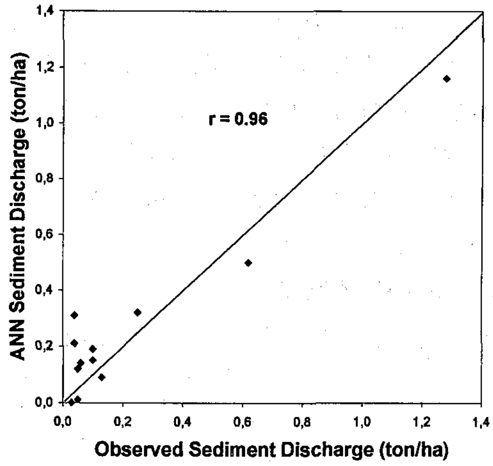

Figure 5 Scatter graph of ANN and observed sediment discharges for the test data set.

5. CONCLUSIONS

An ANN-based runoff-erosion model was developed for predicting and quantifying the sediment discharge as a function of runoff and climatologic data. The model was applied to an experimental plot in a semi-arid region of Brazil. The results were shown to be very trustworthy and therefore this model may produce reliable support for semi-arid areas where historical data is available.

REFERENCES

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