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Estimation of pesticides usage in the agricultural sector in Turkey using Artificial Neural Network (ANN)

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Key words
Artificial neural network, estimation model, pesticides usage, Turkey

1 SUMMARY

This study aimed to estimate the amount of pesticides used in the Turkish agricultural sector and to test the hypothesis that pesticides usage will increase in the future. Artificial neural network (ANN) is a data processing technology whose development was inspired by the data processing technology of the human brain, and is used to estimate pesticides usage. In this study, a model has been developed for the estimation of pesticides usage. The feed forward neural network with back propagation model and the radial bases model are the two model types most commonly used in ANN applications. The most appropriate results of these models were selected by comparing ANN model results with actual results. Comparison of the results showed that the the radial bases ANN model is the most appropriate for estimation of the amount of pesticides used in Turkey. It was observed in the forward estimations that pesticides usage increased in 2007 while the amounts used decreased in 2008 (based on usage in 2007). The model predicts increased pesticide usage for the years 2009-2012.

2 INTRODUCTION

The regular control and monitoring of pesticide usage in agriculture is very important because of the risks posed by pesticides on human, animal and plant health and on the environment. Pesticide usage statistics is also one of the important agri-environmental activities' indicators.

In 2008, many companies were engaged in importation of pesticides in Turkey, accounting for about 42 % of the total number of companies engaged in production and / or importation of pesticides (Anonymous, 2008a). In 2007, the biggest share of the produced pesticides in Turkey was insecticides, followed by herbicides and fungicide, respectively. Fungicide had the biggest share of the total imported pesticides (Anonymous, 2008b).

The present study aimed to estimate the amount of pesticides used in the agricultural sector in Turkey and to test the hypothesis that pesticides usage would increase in the future. Artificial Neural Network (ANN) was used for the estimation of pesticides usage.

ANN works by creating connections between mathematical processing elements and is a type of artificial intelligence that attempts to mimic the way the human brain processes and stores information (Taylor, 2005). The most appropriate ANN model was used to estimate the amount of pesticides used in the Turkish agricultural sector. Nowadays, ANN can be trained to solve problems that are difficult for conventional computers or human beings, and it is good at fitting functions and recognizing patterns (The Mathworks, 2005). This data

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processing technology, which can fit any practical function, should give a good estimation of pesticide usage. . The information generated in the study would also be useful for companies/industries since accurate estimation results of pesticide usage affect the decisions on importation and production of pesticides.

3 MATERIALS AND METHODS

3.1 Materials: Two different approaches were used in order to obtain pesticides usage data. In the first approach, pesticide usage data were obtained from agricultural holdings through a survey. In the other approach, pesticide usage data were obtained by using sales statistics. In Turkey, it is not possible to obtain pesticide usage data representing the whole country through the first approach. Therefore, pesticides sales statistics obtained from the Turkish Statistical Institute (TSI) were used as pesticide usage data in this study. Agricultural land area data was also obtained from TSI (Anonymous, 2008c). In all applications, the data values were divided to 100 000 in order to obtain the values [0-1].

To set the pesticides usage estimation model, feed forward neural network with back propagation and radial bases, the commonly used types of ANN, were used. Matlab Neural Network Toolbox GUI (Graphical User Interface) was used in the ANN applications.

3.2 Methods: ANN, a data processing technology inspired by the data processing technology of the human brain, is used in order to estimate the amount of pesticide usage in following years in this study. This method can be used for the long term forecasting applications (Basheer and Hajmeer, 2000; Donaldson and Kamstra, 1998; Grudnitski and Osburn, 2006; Guoqiang et al., 1998; Hill et al., 1996; Tkacz, 2001). The main unit of ANN is an artificial neural called a node. The structure of an artificial neural is shown in Figure 1.

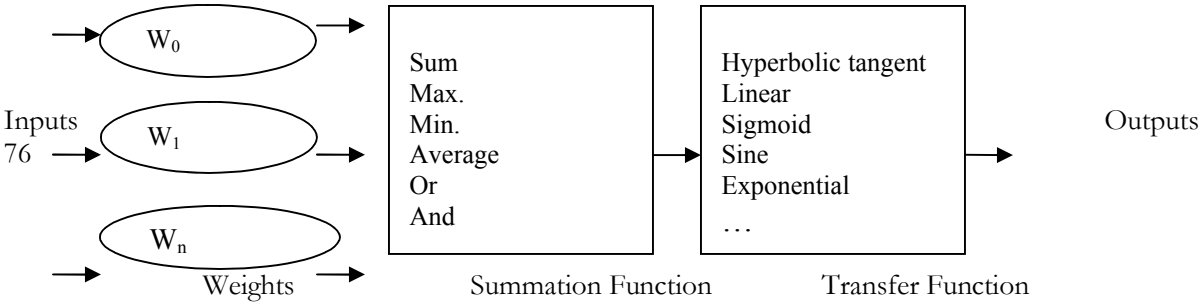

Figure 1: The structure of an artificial neural.

ANN has been trained to perform complex functions in various fields including recognition, identification, classification, speech, vision and control systems. In recent years, neural networks have been applied to many areas of statistics, such as regression analysis and time series analysis (Kajitani *et al*., 2005).

ANN models usually have an input layer which has neurals taking inputs from outside, a hidden layer which has neurals only in contact with the neurals in network and an output layer which transmits outputs to the outside. More than one hidden layer can be used in a network. In many network types, a feed forward neural network with back propagation structure is used. The basis of this structure is that the signals coming from the previous layer are processed (by neurals) and then the output is transmitted to the next layer. The back propagation means that the outputs are transmitted to the previous layer.

The general notation of functional structure of ANN which consists of only one hidden neuron is given in Equation 1

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$y_k = f_k(\alpha_k + \sum_{j \rightarrow k} w_j f_j)$ *Equation 1.*

y_k : output values (pesticides usage),
f_k and α_k : transfer function and bias value in output layer ,
Wj : weights in output layers,
f_j and α_j : transfer function and bias value in the hidden layer.

The transfer function in hidden layer for feed forward neural network with back propagation is given in Equation 2.

$f_j = \text{tansig}(\alpha_j + \sum_{i \rightarrow j} w_{ij} x_i)$ *Equation 2.*

α_j : bias value in hidden layer,
x_i : input values (total agricultural land or years),
w_{ij} : the weight connecting *i* input component to *j* hidden component.

The expression for the net input of a radbas neuron is different from that of other neurons. The net input to the radbas transfer function is the vector distance between its weight vector *w* and the input vector *x*, multiplied by the bias. In radial bases ANN applications, the transfer function for radial basis neuron is given in Equation 3.

$f_j = \text{radbas}(|| w-x || \alpha_j)$; *Equation 3.*
$\text{radbas}(n) = e^{(-n2)}$

To set the pesticides usage estimation model, feed forward neural network with with back propagation and radial bases, which are the commonly used types of ANN were used. First, total agricultural area statistics for the years [1989-2006] were used as input dataset; total agricultural area for the year 2007 was used as test dataset and pesticide usage amounts for the years 1989-2007 were used as output data set. The estimation results of pesticide usage amount for the year 2007 were obtained by using these datasets for both feed forward neural network with back propagation and radial bases types of ANN with different numbers of hidden layers and different numbers of neurons in each hidden layer.

When the results of feed forward neural network with back propagation model were compared to the real value of pesticide usage for the year 2007, the difference between the estimated value closest to the real value, and the actual value was 16.29%, which is not acceptable. The difference between the estimated and real values was also not within acceptable level when the same datasets were used in radial bases type of ANN.

This showed that when the input dataset was selected as total agricultural area, acceptable results were not obtained for both feed forward neural network with back propagation and radial bases types of ANN. So, the models were set with new datasets. The years 1989-2006 were used as input dataset; the year of 2007 was used as test dataset and pesticide usage amount values for the years 1989-2007 were used as output data set.

The input, test and output datasets are shown in Table 1. The estimated value of pesticide usage (amount) for the year 2007 was obtained by using these datasets for feed forward neural network with back propagation type of ANN. Once again, the difference between the estimated value that is closest to the real value and the real value is 16.87%, which is not an acceptable difference.

Table 1: Input, test and output datasets used in selected model.

Input dataset	Output dataset	Input dataset	Output dataset	Test dataset
1988	0.34152	1998	0.29905	2007
1989	0.35349	1999	0.32323	
1990	0.34055	2000	0.33543	
1991	0.2822	2001	0.29798	
1992	0.29645	2002	0.30792	
1993	0.32363	2003	0.35665	
1994	0.28962	2004	0.35123	
1995	0.33243	2005	0.44337	
1996	0.36595	2006	0.36155	
1997	0.33575			

In all feed forward neural network with back propagation applications, mean squared errors (MSE) were used as performance function with "trainlm" algorithm (the most appropriate algorithm) in order to obtain minimum MSE, and 1000 epochs were used for training and tan-sigmoid transfer function, the most appropriate transfer function was used.
New datasets were then used for radial bases type of ANN. The most appropriate estimation result was obtained with this model. The comparison of the estimation result of radial bases ANN model and real value is shown in Figure 2. Radial bases type of ANN consist of two layers: a hidden radial basis layer and an output linear layer. A radial bases transfer function is used in the hidden layer and a linear transfer function is used in the output layer. Radial bases functions can be designed as exact fit or fewer neurons. In fewer neuron model, a goal value is used in contrast to the exact fit model which doesn't use any goal value. In this study, fewer neuron radial bases function was used and the goal value and the spread constant that were closest to real value of radial bases model were selected. According to this criterion, goal value was taken as 0 and spread constant was taken as 0.95.

4 RESULTS AND DISCUSSION

In this study, ANN model was used to estimate the amount of pesticides used in the agricultural sector in Turkey. Feed forward neural network with back propagation and radial bases types of ANN were tested with different input datasets. When both total agricultural land and years were used as input dataset, the estimation results varied significantly from the real value in the feed forward neural network with back propagation ANN model. The radial bases ANN model gave the most appropriate result with the difference between the estimated amount of pesticide usage and the real value for the year of 2007 being 0.62%, which is an acceptable value.

The selected best model was used to make forward estimations, which showed that pesticide usage decreased in 2008 (based on usage in 2007). However, the pesticide usage increases for the years 2009-2012. Therefore, the hypothesis that the tendency of pesticides usage will increase in following years was accepted. The change of pesticides usage by years is given in Figure 3. In the past years, the amount of pesticide usage decreased or increased and the change of it was very flexible. So, according to model, the change of the amount of it is also flexible in following years. In some years the amount of it is increasing sharply, for example in the period 2009 to 2010 and 2010 – 2011.

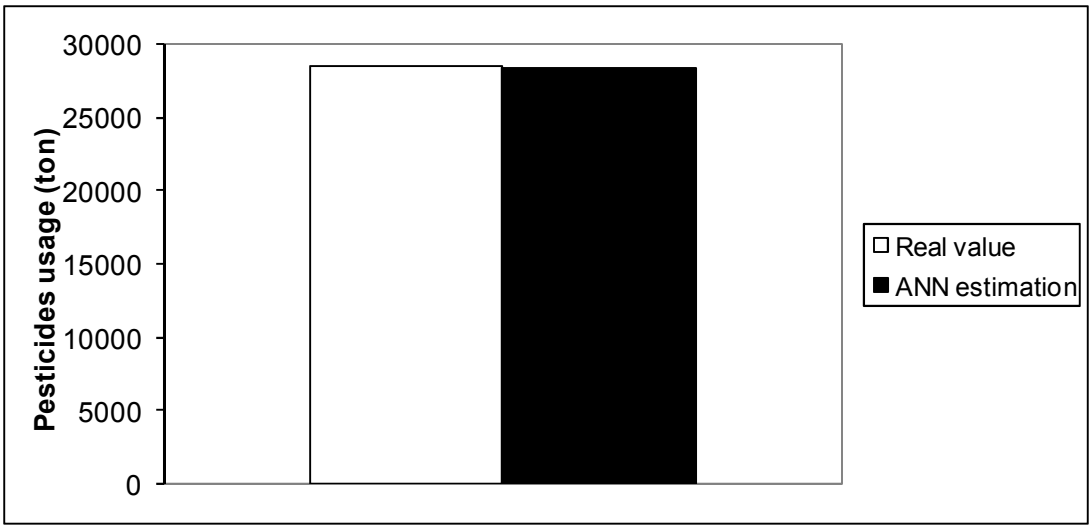

Figure 2: Comparison of the estimation result of radial bases Artificial Neural Network (ANN) model and the real value of pesticides usage in the agricultural sector in Turkey.

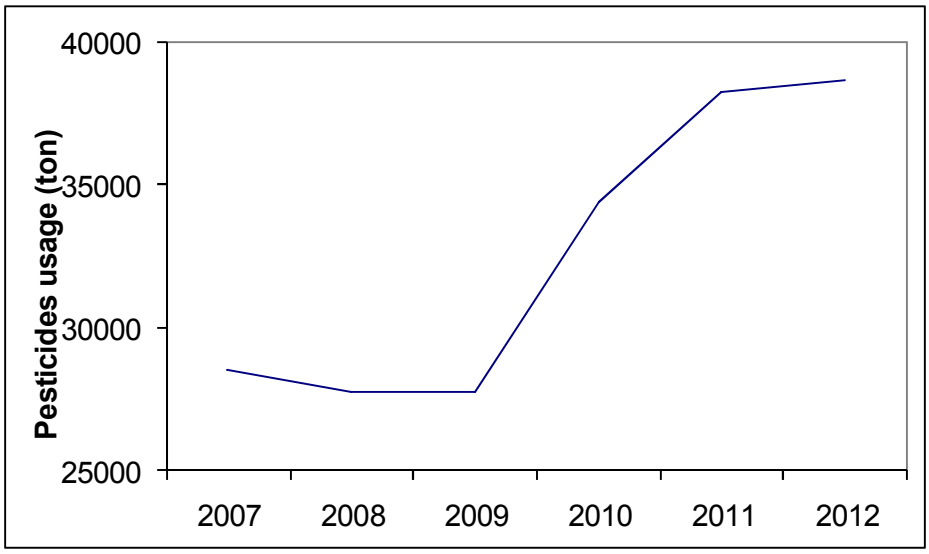

Figure 3: The change of pesticides usage estimated by using radial bases ANN by years.

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