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Estimation of Greenhouse Heating Requirements Using Artifical Neural Networks

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Abstract: In this study by taking into account the latitude, longitude, height, months and mean temperature data of the city and districts of Adana, the heating need for unit base and surface zone is determined. In the model of artificial neural nets the heating need for the green house which is longitude, latitude, height and means temperature data is used as entry layer and the need for heater need is used as exit layer. Of the data belonging to Adana Province and 7 districts; 6 district education data, Adana Seyhan and yüreğir district are used as test data in artificial neural net model. The data has been tested by using Levenberg-Marquardt algoritm and an estimate (R^2) of value from an average of 99% has been found. The average of quadric error square root value is 0.0533 in average and is 0.0021 for education data. The mean absolute error for test data is 0.0485 and 0.0015 for education data. In conclusion, this study focused on the successful estimate of green house heater need by using the model of artificial neural nets.
Key words: Greenhouse, heater need, artificial neural nets, Adana

INTRODUCTION

Agricultural works today should adopt to a rather competitive environment and consequently new smart technologies should be utilized (Mahmoud, 2004). Cultivation of plants in green houses is a way to provide a profitable product (Boodley, 1996; Nelson, 2002; Trejo-Perea et al., 2009). During energy saving and less raw material consumption high amount of harvest is required in agricultural system. Usage of smart technologic systems by agricultural crop producers shall provide important acquirements (Alfons et al., 2001; Korner and Straten, 2008; Trejo-Perea et al., 2009).In present day conditions, the estimation of green house heating requirement by utilization of artificial neural networks (YSA) is possible to have it made. YSA does imitate the learning and possessing ability of human being brain by living or experiencing in order to generate a solution for the problems requiring thinking and observable abilities by a human being. Learning in human beings occurs with the regulations of synaptic connections between nerve cells (neurons). In other words, brain expose consistent an improvement as they are in a learning process by living since their birth. As the number of experiences are increased the synaptic connections are regulated and new connections are formed. By this means learning is realized. This is also valid for YSA. Learning happens to be with using models by way of teaching. It happens by processing the realized input and output data which means the teaching algorithm repeatedly adjusts the weight connection until a convergence is provided (Keskin and Taylan, 2007). As YSA is constituted by congregation of many simple nerve cells has multilayer. Multilayer in YSA with the cells in each layer and their connection to each other transferring information constitutes in a way an information network. Such a network comprises parallel layers and cells inside and communication channels providing sequential connections between them. In recent years artificial nerve networks (YSA) are used in many engineering applications as well as in green house environment control (Seginer, 1997). Frausto H. et al., (2004) with Ehret D. et al., (2008) have used YSA in estimation of cuticula cracking in pepper and tomatoes considering some growth periods in greenhouse environment conditions and plantation mediums during their studies. Linker and Seginer (2004) have tried different YSA models to determine greenhouse internal medium temperature. Similarly, Ferraira et al., (2002) have selected external medium temperature and solar radiation and internal medium relative moisture values as input parameters in order to determine internal medium temperature at an aquatic culture applied in a greenhouse. Linker et al., (1998) had studied on the availability of YSA be used to establish a precise balance between CO_2 enriching requirement and ventilating request in hot climates. They achieved to show the practicability of chilling effect by vaporization in greenhouse with training in neural network by using the data of two summer months in a small greenhouse.

In this study, an estimation is made with artificial neural network for the requirements of heating for unit basement and surface area of the greenhouses of Adana province and its sub-provinces. It also shows that positive results be obtained for heating requirements of the greenhouses by using artificial neural networks with feed-forward back-propagations.

MATERIALS and METHOD

In this study, heating requirement calculation has been made for plastic greenhouses with unit basement areas for the months the heating is required (January, February, March, April, November and December) of the greenhouses of Adana province and its sub-provinces. External temperature and sun radiation is considered when calculating the temperature consumption. Heating energy during the daytime is met by sun energy and heating systems.

Effective heat consumption (q_H) is estimated with equality 1 (Zabeltitz, 1998).

$$q_H = (\frac{Ac}{Ag}) \times U \times (ti - td) - q_{GI} \times D \times \eta \qquad (1)$$

In equality; q_H expresses effective heat consumption, Ac the coat surface area (m^2), Ag the basement area of greenhouse (m^2), U the coefficient of thermal transmittance (W/m^2K), ti the greenhouse required internal medium temperature (^0C), td the external medium temperature (^0C), q_{GI} the intensity of sun radiation (W/m^2), D the rate of sun radiation transmission rate (0,6-0,7), η the conversion factor of radiation energy in greenhouse to heat energy (0,5-0,7). In calculation of the requirement of heating, 17^oC is taken as basis for external temperature of the monthly average and as internal temperature for meeting most of the greenhouse plants' requirements (Anonymous 2008).

In the study, estimation of heating requirement for unit area of the greenhouses has been performed by using artificial neural network model with respect to latitude, longitude, height and average temperature data for the months (January, February, March, April, November and December) heating required in the greenhouses of Adana province and its sub-provinces. Total 48 donnees has been used in artificial neural network. 36 of total donnees has been tested in different network structures as training data.

Artificial neural network model is constituted with three multilayer structure which are entrance layer, secret layer and exit layer. In this study, heating requirements of greenhouses are estimated by constituting single layer and double layer artificial neural model. Neural number in secret layer is taken as 5-6 in separate network structures. A neural network model is shown in *Figure 1.* N unit produces a Y_J output by taking total weighted W_{IJ} of X_I entrance passing this total amount through nonlinear f(.) function.

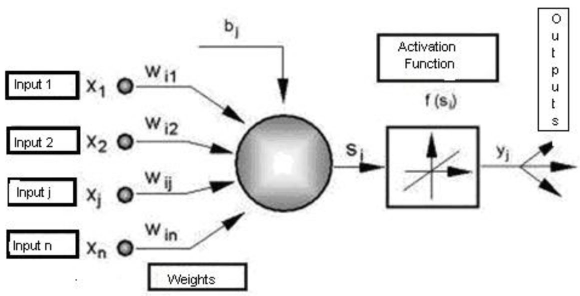

Figure 1. Artificial neural network model

For a multilayer network given in *Figure 1,* input value for any of a unit is expressed by x_i, I= 1,...,N vector and multiplied by a weight value w_{ij}, j= 1,...,v of values coming from other layers (from a secret layer or an entrance layer) and results are congregated along with i index and input values of secret units (v_j) are calculated. For this calculation;

$$v_j = \sum_{i=1}^{N} x_i w_{ij} \qquad (2)$$

J= 1,….N formulation is used. V_j here shows (2) input value of secret neural cell ranked at j and w_{ij} indicates weighted value of interconnection to *j* ranked neural cell from *i* ranked neural cell.

$$Y_j = f(v_j) \qquad (3)$$

Each secret neural cell creates a secret neuron output Y_j by utilizing a sigmoid efficiency function. v_j is calculated by below formula.

$$Y_j = f(v_j) = \frac{1}{1+\exp(-(v_j+\theta_j))} \qquad (4)$$

$f(v_j)$, (4) is the output value of *j* ranked secret neuron. θ_j is the initial value expressed as bias constant. Y_j shall be input of next layer. Later output node's input values are calculated in output layer by using *n=1,…m*

$$IO_n = \sum_{j=1}^{h} w_{jn} Y_{jn} \qquad (5)$$

formulation and IO_n (5) is the input value of the neurons at output layer. These obtained values passed through efficiency function of output layer to calculate output network values $O_n = f(IO_n)$. As a result weight update and learning process is provided by backprop algorithm and "trainlm", "traingd", "traingdx" etc. are most known backprop algorithms used in Artificial Neural Network. Objective of backprop algorithm is to minimize the square error with iteration (step number). Following that, obtaining error gradients by mean-square-error (MSE) equally distributed to input values and input weights are updated and the process initiated again. These procedures are repeated until mean-square-error reaches to requested value and ot determined step number.

$$E = \frac{1}{2}\sum_j \sum_n (K_{jn} - O_{jn})^2 \qquad (6)$$

In formulation K_{jn} expresses the expected output value and O_{jn} the output value produced by neural network. Updating the weights (7);

$$\Delta w_{jn} = -\eta \frac{\partial E}{\partial w_{jn}} \qquad (7)$$

is replaced with method of steepest descent by the formula and endeavored to minimize the error. η is learning ratio, low η value implies very slow descending. In cases with high η value high amplitude oscillations may be observed. One of the solutions brought for this issue is to add a term as $\alpha(w_{jn}^{t} - w_{jn}^{t-1})$ α is called as momentum constant.

Data used in the study has not given better results regarding the estimations in artificial neural network model. Data are normalized by using the 8. equation and data are placed between 0 and 1 values. By using normalized data in artificial neural networks good results are obtained in estimations of heating requirements of the greenhouses.

$$X_n = \frac{(E_R - X_{\min})}{X_{\max} - X_{\min}} \qquad (8)$$

X_R= Real data value,
X_n= Normalized data value,
X_{min}= min value of data to be normalized,
X_{max}= max value of data to be normalized.

In this study each model has been trained by training data set and tested with test data set and Square Root of Root Mean Square Error (RMSE) criterion is calculated by using 9. equation (Landeras G., Ortiz-Barredo A., Lopez J.J., 2008).

R^2 estimation value also found beside one of the best assessment method used in statistical indexes which is Square Root of Root Mean Square Error (RMSE). Related equations are:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left(yi - yi'\right)^2}{N}} \qquad (9)$$

According to R^2 equation; m is the number of the tested data, O_i estimated data in artificial neural network and y_i is calculated heating amount (Traore et al., 2010).

$$R^2 = \frac{\left[\sum_{i}^{m}(yi-\overline{y})(Oi-\overline{O})\right]}{\sum_{i=1}^{m}(yi-\overline{y})^2\sum(Oi-\overline{O})^2} \quad (10)$$

$\overline{y}$ is average of calculated heat quantity (yi) and $\overline{O}$ is average values of estimated heat quantities in neural network. Additionally, mean absolute error (MAE) values are calculated (Neter et al., 1996; Landeras et. al., 2008; Trejo-Perea et al., 2009; Traore et al., 2010).

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|y_i - y_i^{'}\right| \quad (11)$$

In addition to these, linear regression $y = \alpha_1 x + \alpha_0$ is applied to evaluate the estimated heat requirement. x expresses independent variable (heating quantity); α_0 intersection, α_1 declination (Traore et al., 2010).

RESULTS and DISCUSSION

In this study by taking into account the latitude, longitude, height, months and mean temperature data of the city and districts of Adana, the heating need for greenhouses is determined by using artificial neural models. Artificial neural network model consist entry layer, secret layer and exit layer. Artificial neural networks model used in this study is as shown in Figure2. In this study total 48 data of Adana province and its sub-provinces are used. Of the total data 36 is used as training data and 12 as test data. At first stage, data of Adana province and Seyhan sub-province is tested. These values are evaluated by using Levenberg-Marquardt (LM) training algorithm. Test data are tested in different net structures and net structure with best estimation result is preferred. Heating requirement estimation is performed at sub-provinces of Adana province (Yüreğir, Ceyhan, İmamoğlu, Kozan, Yumurtalık and Karataş) within used different net structures.

The best estimation results and statistical performances of heating requirements provided by testing at different net structures of LM training algorithms of Adana province and Seyhan sub-province which are used as test data in artificial neural networks are given in Table 1.

Diverse iteration numbers are used in estimation of the test data and best result is provided at 300 iteration (step) number.

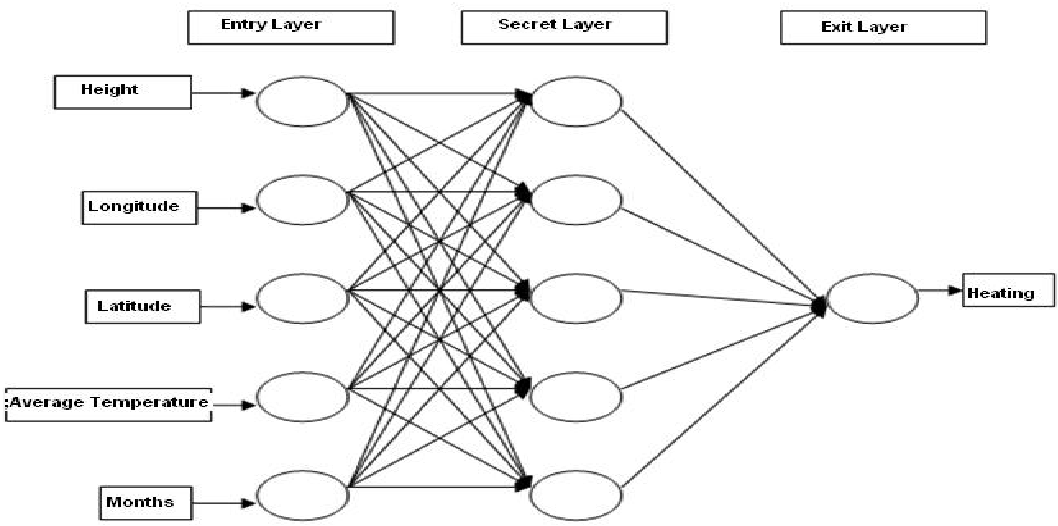

Figure 2. Network structure used in heating requirement of estimated greenhouses in artificial neural network network model

Table 1. Best results and statistical evaluation obtained in estimation of heating requirements of greenhouses by using different net structures for test data

	Net structure	a_1	a_o	R^2	RMSE	MAE	Iteration number
Adana	5*6*1	0.804	0.118	0.9979	0.077	0.070	300
Seyhan	5*5*1	0.778	0.047	0.9962	0.038	0.059	300

Exit data estimation is conducted by using single layer and double layer net structure in LM training algorithms at estimated heating values in Adana province's artificial neural networks. In single and double layer net structure 5 and 6 nerve numbers are used as secret layer. The best estimation results in artificial neural networks for greenhouses of Adana province are obtained as 0.9979 estimation (R^2) value, 0.077 RMSE and 0.059 MAE values at 6*1 net structure. 100 iteration number (step number) used for estimating the training data at different net structures. At 5*1 net structure for Seyhan used as test data; 0.9962 estimation value (R^2), 0.038 RMSE value and 0.059 MAE value is obtained. In artificial neural network model, Adana sub-provinces (Yüreğir, Ceyhan, İmamoğlu, Kozan, Yumurtalık and Karataş) are used as training data. Estimation of training data is performed by using different net structures in LM training algorithm. The best results and statistical evaluations of training data are given in Table 2. Estimation value (R^2) of training data is obtained as 0.999 with 100 iteration number at 5*1, 5*5*1 and 5*6*1 net structures. R^2 value at 6*1 net structure is obtained as 0.998. In net structures 5*1, 6*1, 5*5*1 and 5*6*1 RMSE values 0.0014, 0.0021, 0.0012 and 0.0014 and MAE values 0.0008, 0.0009, 0.0004, 0.0008 obtained respectively.The best result obtained in net structure for estimation value (R^2) of Adana province and Seyhan sub-province which is used as test data in the study is shown in Figure 3 as graphically. Values used as training values of Yüreğir, Ceyhan, İmamoğlu, Kozan, Yumurtalık and Karataş sub-provinces are tested and expressed in Figure 4 graphically. Values estimated 5*1 in figure 4a, 6*1 in Figure 4b, 5*5*1 in Figure 4c and 5*6*1 in Figure 4d in the net structures of training data are shown graphically.

Table 2. Results and statistical evaluation obtained in estimation of heating requirements of greenhouses by using different net structures for training data

Net Structure	a_1	a_o	R^2	RMSE	MAE	Iteration Number
5*1	0.9995	0.0309	0.999	0.0014	0.0008	100
6*1	0.9997	0.0111	0.998	0.0021	0.0009	100
5*5*1	0.9996	0.0230	0.999	0.0012	0.0004	100
5*6*1	0.9995	0.0309	0.999	0.0014	0.0008	100

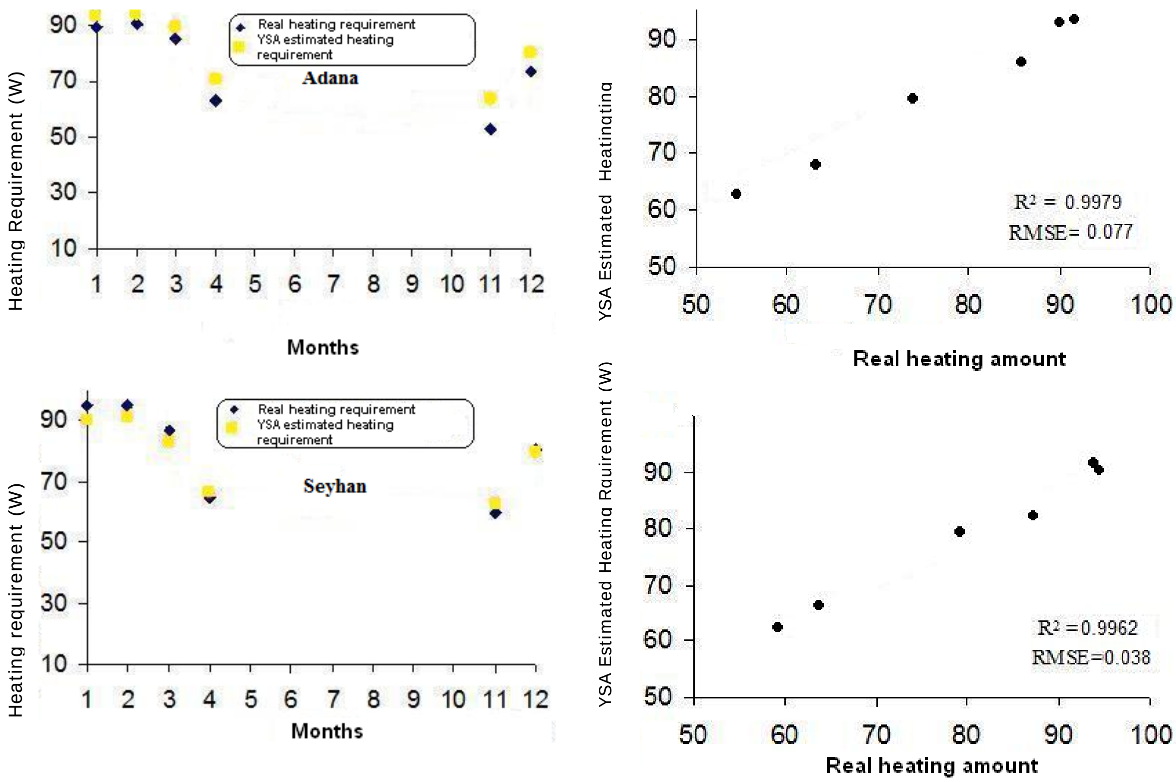

Figure 3. Comparison of heating requirements with real values of greenhouses of test data and estimated artificial neural Networks

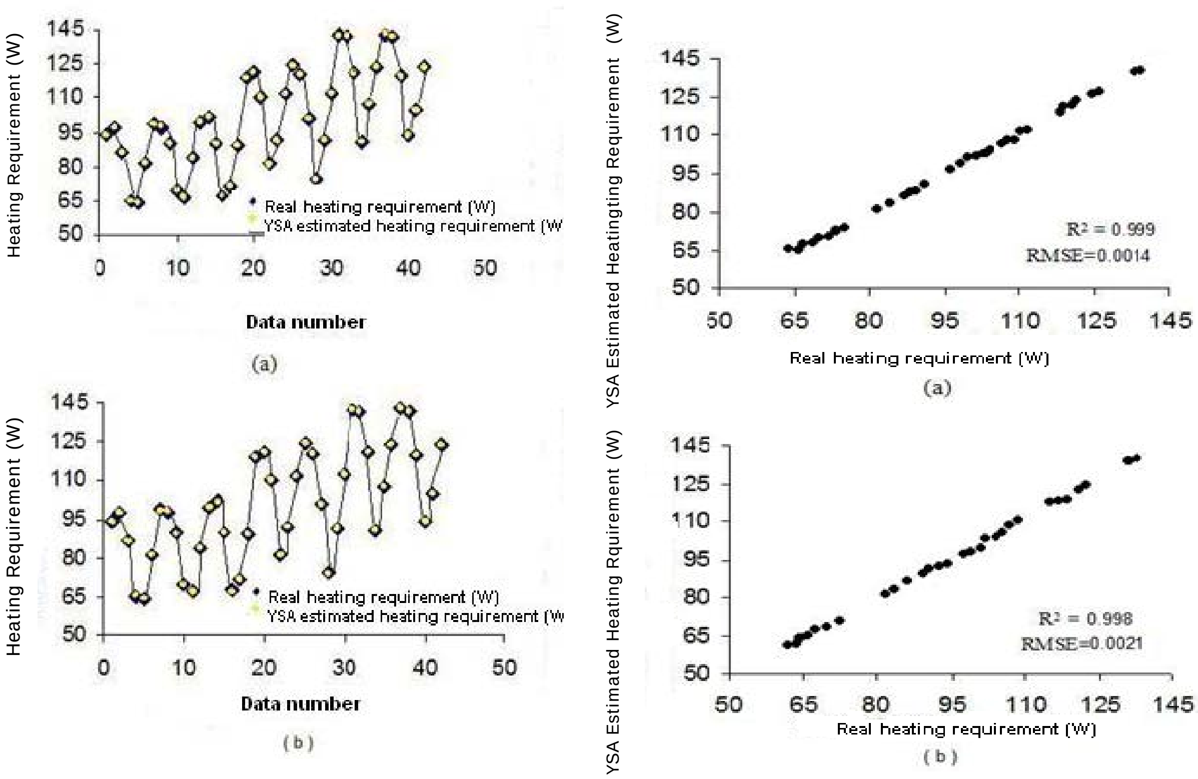

Figure 4. Comparison of real values of greenhouse of training data with the values of estimated heating requirements in artificial neural network

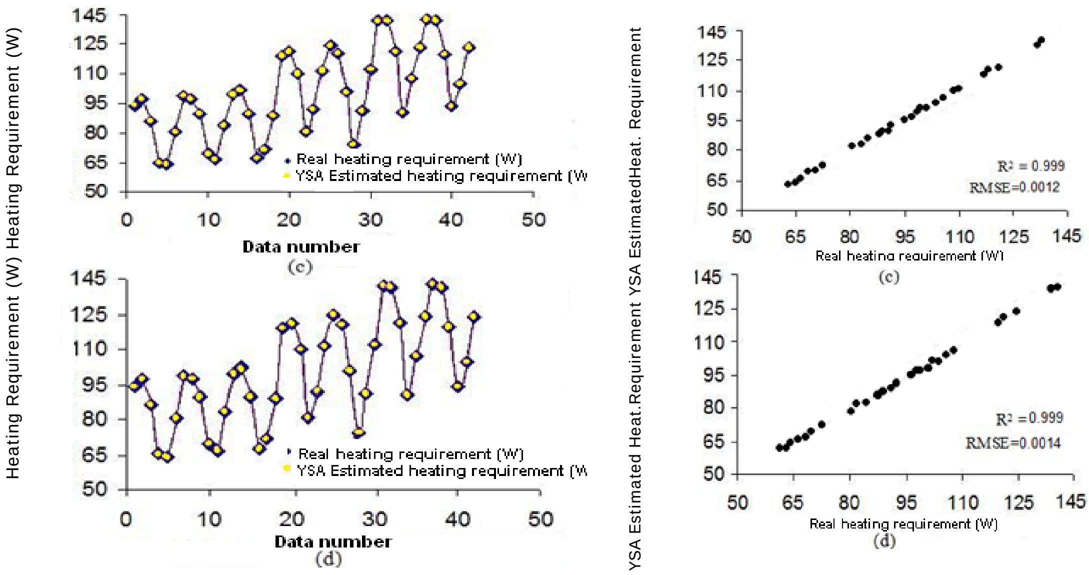

Figure 4. Comparison of real values of greenhouse of training data with the values of estimated heating requirements in artificial neural network

CONCLUSIONS

In this study, analysis of heating requirements per unit area of greenhouses in Adana province and its sub-provinces are performed by utilizing artificial neural networks which is a sub-branch of artificial intelligence implementation. In the study conducted, heating requirement estimations of the greenhouses in Adana province on months basis are made by using latitude, longitude, height and average temperature data within different net structures per LM training algorithm. Statistical analysis such as R^2, RMSE and MAE are performed in the net structures which provide the best result for test and training data. As for that it is observed that the artificial neural network method has appropriate area of use in engineering fields. It is seen that the method is the most appropriate for the solutions of the problems by using convenient training set with artificial neural networks. Artificial neural networks is an algorithm; determining, deducing, deducing from present data in insufficient data cases, having ability to reach the best conclusion by using less data, learning, remembering in computer environment. For these advantages provided by artificial neural networks, it is used in many branches especially in the engineering field.

REFERENCES

Anonymous,2008. Heating, Greenhouses, American National Standard, 2003-

Alfons, G.J.M.et. al.,2001. Investment decision making in Dutch Nether. J. Agric. Sci., 49: 357–368.

Boodley, J.,1996 The Commercial Greenhouse, 2nd edition, Thomson Delmar Learning, pp:123–135.

Ehret, D.L. et.al.,2008. Artificial Neural Network Modelling to Predict Cuticle Cracking in Greenhouse 61, 108–116.

Ferreiraa, P.M., et al.,2002. Neural Network Models in Greenhouse Air temperature Prediction, 43: 51–75.

Frausto, H.U., et al.,2004. Greenhouse Temperature Using System İdentification by Means of Neural Networks, Neurocomputing 56, 423 – 428.

Keskin, M. E., and Taylan, E. D.,2007. Karadeniz Havzasında Akımların Modellemesi. İMO Teknik Dergi, 4271.

Korner, G. and Straten, V.2008. Dynamic greenhouse climate control strategies. Computers Electronics Agric., 60:18–30.

Landeras, G.,et al., 2008. Comparison of Artificial Neural Network Models and Water Management, 95:553-565.

Linker, R., e al.,1998.Greenhouse Modeled With Neural Networks, Electronics in Agriculture 19, 289–310.

Li Linker, R. and Seginer, I., 2004, Greenhouse Temperature modeling: Mathematics and Computers in Simulation 65.

Mahmoud, O.,2004,A Computer-based monitoring system to maintain optimum air temperature and Int. J. Agric. Biol.,6:1084–1088.

Nelson, P.V.,2002, Greenhouse Operation and Management, 6th edition, pp:128–147.

Neter, J., et al.,1996, Applied Linear Statistical Models, 4th edition, pp: 266–279. Irwin.

Seginer, I., 1997, Some Artificial Neural Network Applications to Greenhouse Environmental Control, Computers and Electronics in Agriculture, 18, 167-186.

Trejo-Perea, Met al., 2009, Greenhouse Energy Consumption Prediction using Neural Networks Models. Int. J. Agric. Biol., Mexico, Vol. 11, No. 1.

Traore S., et al.,2010, Artificial Neural Network for Modeling Evapotranspiration Complex Process in Sudano Zabeltitz, C.V. 1998, Solar Energy. Energy Conservation and Renewable Energies for Greenhouse 3:122-128.