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Evaluation of heat transfer mathematical models and multiple linear regression to predict the inside variables in semi-solar greenhouse

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Introduction

Controlling greenhouse microclimate not only influences the growth of plants, but also is critical in the spread of diseases inside the greenhouse. The microclimate parameters were inside air, greenhouse roof and soil temperature, relative humidity and solar radiation intensity. Predicting the microclimate conditions inside a greenhouse and enabling the use of automatic control systems are the two main objectives of greenhouse climate model. The microclimate inside a greenhouse can be predicted by conducting experiments or by using simulation. Static and dynamic models are used for this purpose as a function of the metrological conditions and the parameters of the greenhouse components. Some works were done in past to 2015 year to simulation and predict the inside variables in different greenhouse structures. Usually simulation has a lot of problems to predict the inside climate of greenhouse and the error of simulation is higher in literature. The main objective of this paper is comparison between heat transfer and regression models to evaluate them to predict inside air and roof temperature in a semi-solar greenhouse in Tabriz University.

Materials and Methods

In this study, a semi-solar greenhouse was designed and constructed at the North-West of Iran in Azerbaijan Province (geographical location of 38°10′ N and 46°18′ E with elevation of 1364 m above the sea level). In this research, shape and orientation of the greenhouse, selected between some greenhouses common shapes and according to receive maximum solar radiation whole the year. Also internal thermal screen and cement north wall was used to store and prevent of heat lost during the cold period of year. So we called this structure, ‘semi-solar’ greenhouse. It was covered with glass (4 mm thickness). It occupies a surface of approximately 15.36 m^2 and 26.4 m^3. The orientation of this greenhouse was East–West and perpendicular to the direction of the wind prevailing. To measure the temperature and the relative humidity of the air, soil and roof inside and outside the greenhouse, the SHT 11 sensors were used. The accuracy of the measurement of temperature was ±0.4% at 20 °C and the precision measurement of the moisture was ±3% for a clear sky. We used these sensors in soil, on the roof (inside greenhouse) and in the air of greenhouse and outside to measure the temperature and relative humidity. At a 1 m height above the ground outside the greenhouse, we used a pyranometre type TES 1333. Its sensitivity was proportional to the cosine of the incidence angle of the radiation. It is a measure of global radiation of the spectral band solar in the 400–1110 nm. Its measurement accuracy was approximately ±5%. Some heat transfer models used to predict the inside and roof temperature are according to:

$$\frac{dT_a}{dt} = \frac{Q_{a-s} - Q_{a-o} - Q_{a-ri} - Q_{nwi-nwo}}{\circ_a \times c_{p-a} \times V_a} \quad (1)$$

$$\frac{dT_{ri}}{dt} = \frac{Q_{rd-ri} + Q_{a-ri} + Q_{s-ri} - Q_{ri-o} - Q_{ri-sk}}{\circ_r \times c_{p-r} \times V_r} \quad (2)$$

The regression model was formed for output (T_{ri} and T_a) using four inputs for each of them according to:

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Inside air temperature (T_a), solar radiation on the roof (I_r), wind speed (v_o), outside air temperature (T_o).
Inside soil temperature (T_s), solar radiation on the roof, roof temperature (T_{ri}), outside air temperature.

Results and Discussion

Results showed that solar radiation on the roof of semi-solar greenhouse was higher after noon so this shape can receive high amounts of solar energy during a day. From statistical point of view, both desired and predicted test data have been analyzed to determine whether there are statistically significant differences between them. The null hypothesis assumes that statistical parameters of both series are equal. P value was used to check each hypothesis. Its threshold value was 0.05. If *p* value is greater than the threshold, the null hypothesis is then fulfilled. To check the differences between the data series, different tests were performed and *p* value was calculated for each case. The so called *t-test* was used to compare the means of both series. It was also assumed that the variance of both samples could be considered equal. The variance was analyzed using the *F-test*. Here, a normal distribution of samples was assumed. The results showed that the *p* values for heat model in all 2 statistical factors (Comparison of means, and variance) is lower than regression model and so the heat model did not have a good efficient to predict T_{ri} and T_a. RMSE, MAPE, EF and W factor was calculated for to models. Results showed that heat model cannot predict the inside air and roof temperature compare to regression model.

Conclusions

This article focused on the application of heat and regression models to predict inside air (T_a) and roof (T_{ri}) temperature of a semi-solar greenhouse in Iran. To show the applicability and superiority of the proposed approach, the measured data of inside air and roof temperature were used. To improve the output, the data was first preprocessed. Results showed that RMSE for heat model to predict T_a and T_{ri} is about 1.58 and 6.56 times higher than this factor for regression model. Also EF and W factor for heat model to predict above factors is about 0.003 and 0.041, 0.013 and 0.220 lower than regression model respectively. We propose to use Artificial Neural Network (ANN) and Genetic Algorithm (GA) to predict inside variables in greenhouses and compare the results with heat and regression models.

Keywords: Heat transfer, Model efficiency, Modeling, Semi-solar greenhouse