Artificial Neural Networks (ANNs) Approach for Stomatal Resistance Model

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Introduction

Two-layers resistance model of heat fluxes exchange, described in Nakano and Cho (1985) and Saptomo *et al* (2003), involves external and internal resistance performed by vegetation system. The external resistances are physical processes that can be approached by mathematical model. Internal resistance in the other hand involved the biological processes inside the plant body which are either complex or contain some uncertainty.

Artificial neural networks (ANNs) attempt to simulate the function of human brain by means of massively parallel processing artificial neurons and a learning rule. It learns the relationship between the input and output variables by studying previously recorded data and ANNs can be used as an approach of the complex system of biological processes such as transpiration.

In this study ANNs was used to develop an alternative approach for stomatal resistance of grass.

ANNs stomatal resistance model

The resistance that occurs in latent heat transfer is obtained by taking into account the stomatal resistance r_s and leaf boundary aerodynamic r_a. Empirical equations were commonly used to approach stomatal resistance, one of the example which was used in Nakano and Cho (1985)

$$r_s = r_{min} + b / [I + b / (r_c - r_{min})] \quad (1)$$

where I is the amount of radiation absorbed by the plant, r_{min} is the minimum stomata resistance, r_c is cuticle resistance and b is a constant. This equation used radiation energy and minimum resistance as input parameters, where minimum resistance depends on water content or wetness condition.

The input layer of the networks involves two nodes as an input of wetness and radiation energy information. The radiation energy information was given as the amount of shortwave radiation absorbed by the plant body. Vapor pressure is given to represent the wetness condition information. The constructed ANNs has two inputs, 10 hidden nodes and one outputs, as shown in Fig.1.

The other constant and parameters exists in stomatal resistance equation (b, r_{min} and r_c) then become the internal function of the networks.

The ANNs was conducted using error back propagation technique which can be found in many text books of artificial intelligent application such as Cartwright (1993) and Haykin (1999).

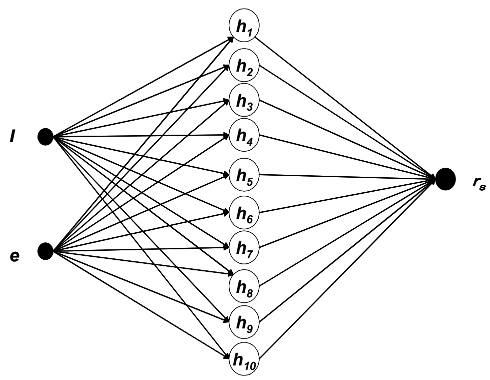

Figure 1 ANNs model for stomatal resistance

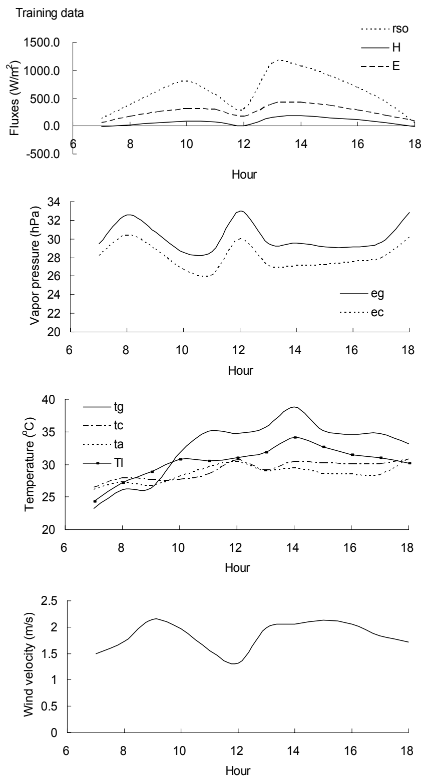

Figure 2 Input data for ANNs adjustment program

Keywords : resistance model, evapotranspiration, artificial neural network

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The ANNs was specially built to be a sub-model in two-layer resistance model and the adjustment of the networks was conducted through simulation using this model since the actual data of somatal resistance was not available. Variations of the measured data that were observed at the grass field on August 19, 2003 for the training input are shown in Fig.2.

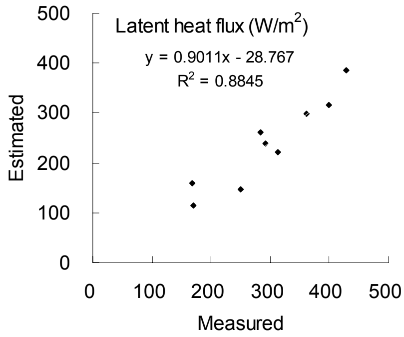

Figure 3 Latent heat flux

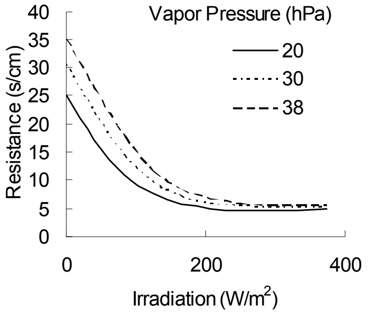

Figure 4 Relation of resistance and irradiation

The measured and estimated latent heat flux are compared in the Fig.3. Fig.4 shows the relation between stomatal resistance and irradiation for different condition of air vapor pressure resulted from this model. However a clear relation between stomatal resistance and leaf or soil wetness was not disclosed.

Heat fluxes analysis

Using the trained ANNs resistance models, the energy balance of grass field was simulated. Figure 5 shows the energy balance resulted from the simulations using ANNs stomatal resistance sub-model. Using the same parameters simulation using mathematical model of stomatal resistance was also conducted with $b = 0.5$, $r_{min} = 1$ s/cm and $r_c = 40$ s/cm, and its results of latent and sensible heat fluxes are compared in Fig. 6.

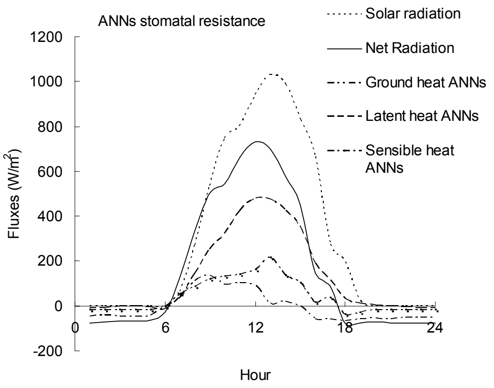

Figure. 5 Energy balance simulated using ANNs stomatal resistance sub-model

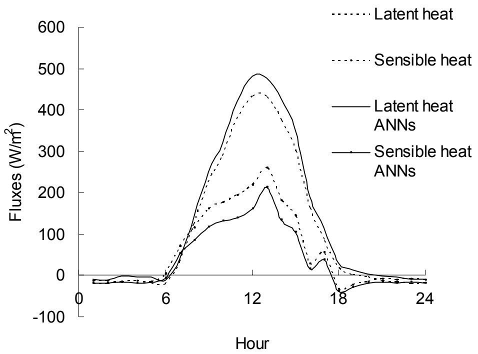

Figure 6 Sensible and latent heat fluxes using ANNs and mathematical model.

Conclusion

ANNs model offers an alternative approach for plant resistance to the release of vapor through its stomata. The model can be conveniently integrated into the two-layer resistance model. The indirect training performed for this model is applicable when the actual data of stomatal resistance is not available. This model is unique for the specific vegetation types and condition, and also specialized for the simulation model used in this study.

References

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