Marras, Serena; Spano, Donatella Emma Ignazia; Sirca, Costantino Battista; Duce, Pierpaolo; Snyder, Richard L.; Pyles, Rex David; Paw U, Kyaw Tha (2008) *Advanced-Canopy-Atmosphere-Soil Algorithm (ACASA model) for estimating mass and energy fluxes.* Italian Journal of Agronomy, Vol. 3 (3 Suppl.), p. 793-794. ISSN 1125-4718.

http://eprints.uniss.it/3722/

Italian Journal of Agronomy
Rivista di Agronomia

An International Journal of Agroecosystem Management

10th Congress of the European
Society for Agronomy
15-19 September 2008, Bologna, Italy

E/A

Multi-functional Agriculture
Agriculture as a Resource for Energy
and Environmental Preservation

The Official Journal of the
Italian Society of Agronomy

Ital. J. Agron. / Riv. Agron., 2008, 3 Suppl.

Advanced-Canopy-Atmosphere-Soil Algorithm (ACASA Model) for Estimating Mass and Energy Fluxes

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Introduction

There is a recognized need to improve land surface models that simulate mass and energy fluxes between terrestrial ecosystems and atmosphere. In particular, long-term land planning strategies at local and regional scales require better understanding of agricultural ecosystem capacity to exchange CO_2 and water. One of the more elaborate models for flux modelling is the Advanced Canopy-Atmosphere-Soil Algorithm (ACASA) model (Pyles et al., 2000), which provides micro-scale and regional-scale fluxes. The ACASA model allows for characterization of energy and carbon fluxes. It is a higher-order closure model used to estimate fluxes and profiles of heat, water vapor, carbon and momentum within and above canopy using third-order closure equations. It also estimates turbulent profiles of velocity, temperature, humidity within and above canopy. The ACASA model estimates CO_2 fluxes using a combination of Ball-Berry and Farquhar equations. In addition, the effects of water stress on stomata, transpiration and CO_2 assimilation are considered. The model was mainly used over dense canopies (Pyles et al. 2000, 2003) in the past, so the aim of this work was to test the ACASA model over a sparse canopy for estimating mass and energy fluxes, comparing model output with field measurements taken over a vineyard located in Montalcino, Tuscany, Italy.

Methodology

The experiment was conducted at Col d'Orcia vineyard near Montalcino, Tuscany, Italy (43° 05′ N, 11° 48′ E, 220 m elevation above sea level). The canopy was estimated to have about 50% ground cover. ACASA model results were compared with eddy covariance (EC) measurements taken during the fruit set (June-July) and veraison (August) phenological stages in 2005 and 2006. During 2006, measurements covered the entire period from the end of June to August. EC system consisted of a sonic anemometer (CSAT3, Campbell Scientific, Logan, UT, USA), and an open path gas analyzer (LiCOR 7500, Lincoln, NE, USA). Net radiation, soil heat flux, air temperature, humidity, and precipitation were also measured.

The model was set to use ten air layers within the canopy and ten above it. The number of soil layers was set to 15 with adjustable thickness per layer. Input files required to run the model, include: (1) plant and soil data, leaf optical and physiological characteristics, (2) meteorological (30 minute) data, and (3) initial soil data. ACASA was run initially to select morphological input that gave better results. The August 2005 measurement period was used for model parameterization, and the other measurement periods were used for model validation. ACASA model accuracy was evaluated using linear regression, the root mean squared error (RMSE), the mean absolute error (RA), and the mean bias error (MBE). Regression significance between simulated and measured fluxes was evaluated by the F test. Significance was tested at 0.95 and 0.99 levels.

Results

Simulated energy and mass fluxes during 2005 and 2006 were compared with measurements at half-hourly time steps. Modeled data showed a good energy balance closure. ACASA estimates of net radiation were excellent. Sensible (H) and latent heat (LE) flux predictions exhibited only small differences between modeled and observed data (Figs. 1, 2). The ACASA soil heat flux was slightly lower than observations. The model most likely did not properly account for more exposed, bare soil in the sparse canopy. Regarding CO_2 flux, model estimates were good with both positive and negative fluxes well predicted (Fig. 3). In addition, ACASA was able to capture the increase in respiration (positive net ecosystem exchange), which occurred after rainfall events. Statistical analysis showed that errors of ACASA predictions were low.

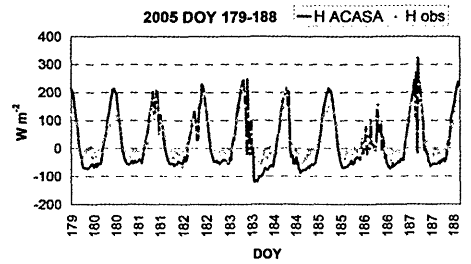

Figure 1. Comparison between simulated and observed sensible heat flux (H) during June-July 2005.

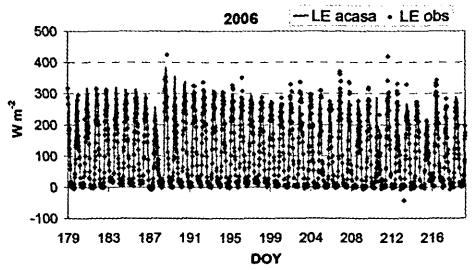

Figure 2. Comparison between simulated and observed latent heat flux (LE) during June-August 2006.

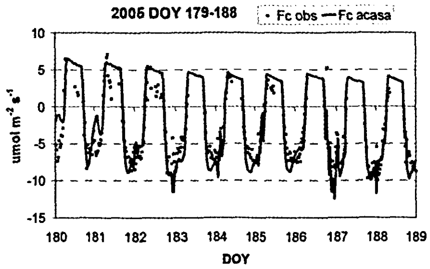

Figure 3. Comparison between simulated and observed CO_2 flux (Fc) during June-July 2005.

Conclusion

The use of ACASA to predict energy and mass fluxes between the vegetation and atmosphere is promising. After some refinements to the input parameters and model codes, the ACASA model could greatly improve our ability to estimate fluxes over agricultural ecosystems at both local and regional scales.

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