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A METHOD TO DETERMINE POTENTIAL EVAPOTRANSPIRATION RATES IN TEA PLANTATIONS

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Information on evapotranspiration (ET) is needed for many applications in tea plantations for planning and natural resource management. However, most commonly used prediction equations have not been tested for extreme and prevailing weather conditions in the tea plantations of Sri Lanka. Available, weather records are also not adequate to use these equations. An empirical model was hence developed with the most commonly available weather records, namely maximum and minimum temperatures with pan evaporation. This equation was evaluated by the Priestly-Taylor and Penman-Monteith equations for accuracy. It was found that the temperature based equation was reasonably in close agreement with measured pan evaporation measurements for monthly and annual predictions.

INTRODUCTION

Knowledge of soil moisture studies are of practical value for researchers and plantation managers, because of its importance in many weather sensitive agricultural problems. As a soil moisture management tool, it helps in explaining variations in agricultural production, estimation of crop yields based on weather records, defining micro-climatic zones, etc.

Evapotranspiration (ET) in the hydrologic cycle represents an important exchange of heat and water vapor between earth surface and atmosphere, since about 70 per cent of the land precipitation is returned to the atmosphere by evapotranspiration from soil and vegetation. It is the combined water loss through transpiration from plant and evaporation from the soil surface that constitutes evapotranspiration.

Evapotranspiration is a energy requiring process. Information on evapotranspiration is important in climatological classifications and in agricultural studies related to crop water requirements. The rate of evapotranspiration from soil and vegetation depends on the available energy to vaporize water, on the amount and tension of water in the soil as well as on the type and conditions of plant and soil surfaces but as these factors change continually with time, evapotranspiration is a function of meteorological, physical and biological processes.

Potential ET is used as a starting point for computation in most moisture budget studies. Under a given set of atmospheric soil and plant conditions actual ET is always equal to or less than potential ET.

Since the introduction of the concept of potential ET independently by Thornthwaitte (1948) and Penman (1948) several technologies had been proposed for the calculation of potential ET which include (a) direct measurements viz. lysimeters, energy budgets and mass transfer theories of evaporation and (b) estimates from evaporation measurements and empirical relationship with meteorological factors (Baier, 1965). However, in tea plantations potential ET determinations are not available; in most instances, available parameters are maximum and minimum temperatures. If these parameters could be related to potential ET rates empirically it will prove to be useful tools in agricultural management. However, there is a paucity of work on this aspect. The following study was therefore undertaken with a view to relate maximum and minimum temperatures to potential rates empirically and compare the model predictions with (a) Penman-Monteith equation and (b) Priestly-Taylor equation and (c) actual pan evaporation from that location where weather data is available.

MATERIALS AND METHODS

The models used for comparison were the Penman-Monteith equation and the Priestly-Taylor equation. The Penman-Monteith equation has both radiative and aerodynamic components in addition to biologically based canopy resistance and physically based aerodynamic resistance term in the wind function. The data requirement for this model are daily mean temperature, radiation, vapor pressure deficit and daily wind. Priestly and Taylor (1972) suggested that under near saturated condition the aerodynamic component of Penman-Monteith equation would be less important and is proportional to the radiative term into the Penman equation. Their model was intended for larger area prediction, but because of its simplicity it has been adopted for many short term, local applications. It requires less input data than the Penman-Monteith equation. Our model was a correlation between maximum and minimum temperature and pan evaporation for that location. This model was used to predict potential ET for the other years.

Weather Records

All the weather records were obtained from the meteorological station at St. Coombs Estate, Talawakele (1382 mAMSL; Lat 6.50; Long 80.40). Daily net solar radiation was modeled using Campbell (1977).

Maximum and minimum temperatures were measured with mercury in glass thermometer as well as by the alcohol in glass thermometer situated in Stevenson screen. Dry and wet bulb temperatures were measured at 0830 h and at 1530 h. All temperature measurements were in degree Celsius. Pan evaporation was measured with US Class A Pan.

The weather records selected for ET prediction were from (a) normal year where the rainfall was equal to the average rainfall for that location – 1986; (b) a relatively wet year where the rainfall was greater than the average annual rainfall – 1987, and (c) a relatively dry year where the rainfall was less than the average annual rainfall – 1983.

RESULTS AND DISCUSSION

The following empirical equation best fitted regression between the maximum and minimum temperature to pan evaporation of St. Coombs Estate, Talawakele for the year 1987.

$$PANET = -1.8318-0.2212*MINT+0.3104*MAXT$$

where PANET is the pan evaporation and MINT and MAXT are the daily minimum and maximum temperatures respectively. The R^2 value for this fitted equation is 0.46 and the F ratio of this model is 144.56 indicating that the regression was significant at the 5% probability level. The R^2 value indicates that maximum and minimum temperatures contribute to 46% to the fitted model to explain the pan evaporation. This R^2 value can be improved by including all the other weather parameters such as radiation, wind and vapor deficit. But the contribution will be less compared to that of maximum and minimum temperatures (Sivendran and Senaratne, unpublished data). The main reason for fitting a model with maximum and minimum temperatures is that these measurements can be easily recorded in tea plantation while the direct measurements of pan evaporation are usually not done. A summary of predictions of annual ET and pan evaporation are given in Table 1. Predicted ad measured ET rates on a monthly basis for the years 1983, 1986 and 1987 are presented in Figures 1, 2 and 3 respectively. All the Figures show a 1 : 1 line.

TABLE 1–*Predicted and measured* ET *rates (mm/year)*

Year	*Priestly-Taylor*	*Penman-Monteith*	*Pan*	*Temp.*
1983	1337	1470	1240	1135
1986	1184	1257	938	938
1987	1303	1327	1039	1028

Always, for annual predictions ET rates predicted by Priestly-Taylor and Penman-Monteith equation were higher than when measured by pan and predicted by the temperature model. This may be due to the presence of advection factor in the Priestly-Taylor equation and the aerodynamic factor in Penman-Monteith equation.

When the wind is higher, as in the case of the year of 1983, the Penman-Monteith equation over predicted ET rates than the other models. This is due to the presence of a wind function in the Penmann-Monteith equation. Others have reported difficulty in applying a combination equation in windy locations. Hill, Johns and Frevert (1983) limited wind speed at 160 km/day (1.9 m/s) to make the Penman equation to work at selected locations. On the other hand, pan measurements and temperature based empirical model predictions were almost the same. This clearly shows that ET rates are mainly a function of temperature. However, whether the constants in this equation have any physical meaning and whether the the same constants could be used to predict ET rates elsewhere are yet to be seen. It is interesting to note that the Jensen-Haise equation which uses temperature and radiation as input parameters also has location specific constants (Jenson and Haise, 1963).

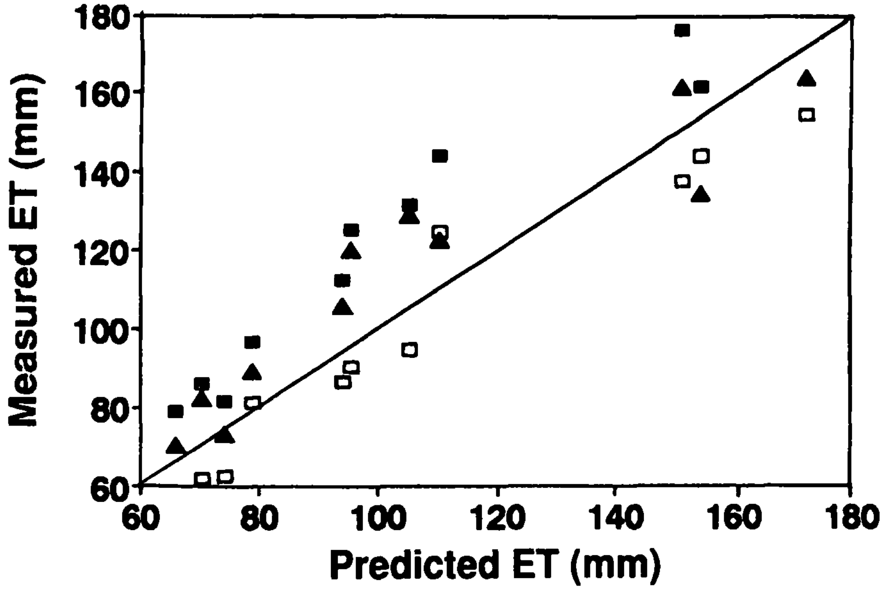

Fig. 1 – Predicted and measured ET rates for 1983

▲ Priestly-Taylor equation
■ Penman-Monteith equation
□ Temperature based equation

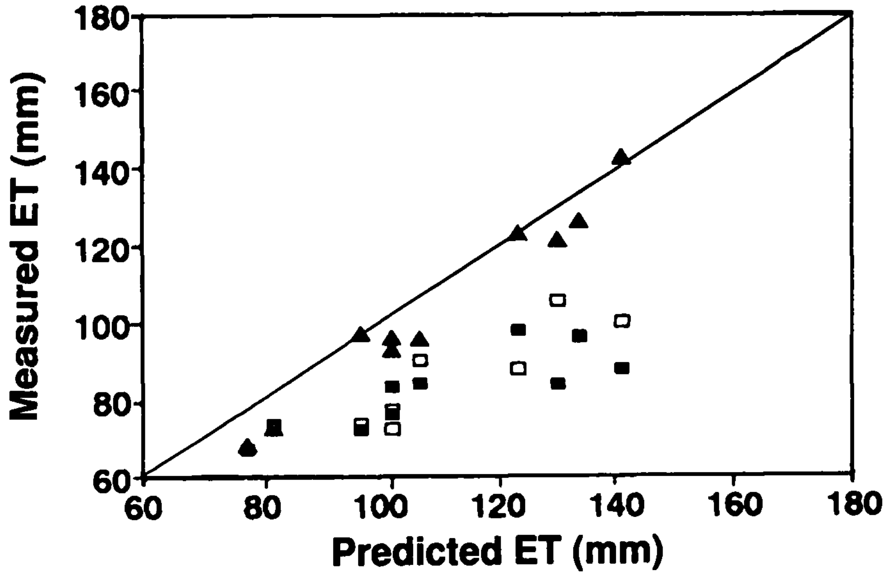

Fig. 2 – Predicted and measured ET rates for 1986

▲ Priestly-Taylor equation
■ Penman-Monteith equation
□ Temperature based equation

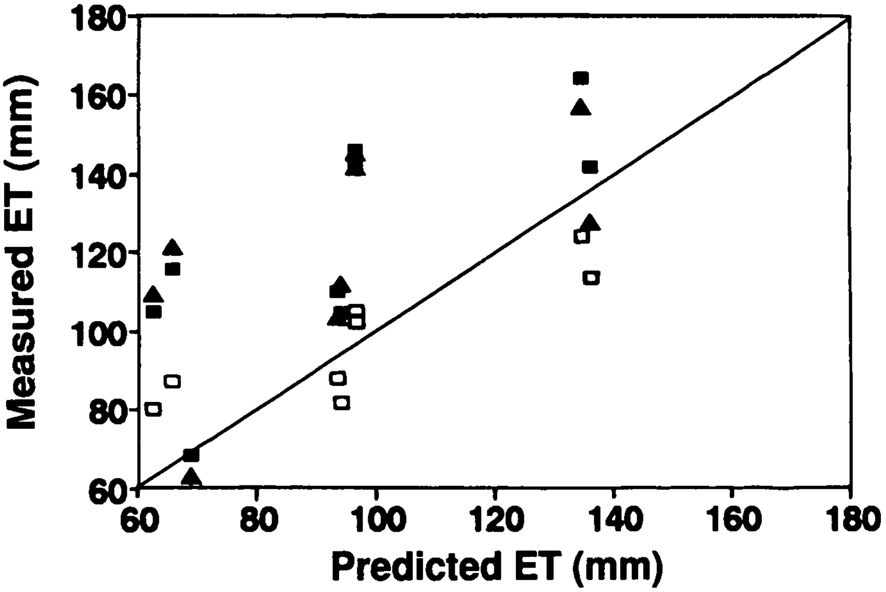

Fig. 3 – Predicted and measured ET rates for 1987

▲ Priestly-Taylor equation
■ Penman-Monteith equation
□ Temperature based equation

Even in the case of monthly predictions, temperature based model predicted values are more closer to pan measurements than the other two. However, there is a variation between temperature based model and that measured with pan during the dry period.

During the wet period, temperature based model predicted more closer to that measured with the pan than the other two models.

CONCLUSIONS

The model based on maximum temperature to predict monthly and annual ET rates agrees reasonably well with measured pan evaporation data for three different annual weather conditions for Talawakele. However, the usefulness of this equation for other locations is yet to be evaluated.

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