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Development and Testing of a Soil Moisture Deficit Indicator for Irrigation Scheduling

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ABSTRACT. Irrigation scheduling is important to prevent yield loss due to shortage or excess application of irrigation water. A device which indicates the soil moisture deficit by simulating rainfall/irrigation input and crop Evapo-Transpiration (ET) output was constructed and tested with, a) free water evaporation from a USWB Class A pan evaporimeter, b) reference crop ET estimated from Penman method, and c) potential ET of grass grown in a Thornthwaite type drainage lysimeter. The results showed that the indicator can be used for irrigation scheduling as a reliable technique. The pan evaporation method is more suitable than the Penman method in estimating reference crop ET, while the latter overestimated it by 25%.

INTRODUCTION

Determination of available soil water, rate of soil water depletion, when to irrigate and the amount of water to be applied are some of the important components in any irrigation scheduling programme. Depending upon the availability of resources, various approaches are now being adopted to determine these components.

Available soil water content is only an estimate of the amount of water, a crop abstract from the soil. A crop should be irrigated when the available water level has been depleted to a critical depletion level. Constant monitoring of soil moisture content is thus required for this purpose. Soil moisture content in the field can be measured directly by gravimetric and neutron probe method (Van Bavel *et.al.*, 1963). Tensiometer, gypsum blocks and salinity sensors can be used to take indirect measurements of soil moisture content (Rhoades *et. al.*, 1981).

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Estimation of crop water requirement with empirical formulae to estimate crop water use is widely adopted to determine the time at which the crop should be irrigated. Some computer programs are also being developed to estimate crop ET (Lambart *et al.*, 1981). Evaporation pan, such as United States Weather Beareau (USWB) class A and wash tub evaporation pan can be used to estimate crop ET (Gerald *et al.*, 1981). Also, some advanced techniques which help to relate plant characteristics to the plant water status are available to determine when to irrigate the crop (Slack *et al.*, 1981).

The need of climatological information and the complexity of calculation procedure are the main drawbacks in popularizing the use of the empirical method of irrigation scheduling amongst the average farmer. The high cost of moisture counter of the gypsum block and the tensiometer in addition to the knowledge required to use them are some of the main causes for their limited use. The exorbitant cost of neutron probe prevents its use for scheduling even in developed countries.

The drawbacks or limitations mentioned above often resulted in farmers abandoning the use of irrigation scheduling techniques in irrigated agriculture. As a result much valuable water is wasted. This leads to water shortages during the growing season resulting in lower yield. Inability to identify the correct time to irrigate may also lead to yield losses specially when there are water stresses at the critical stages of crop growth.

The atmometer has been a popular indicator for irrigation scheduling which simulates the ET from vegetation (Livingston, 1935). Atmometer can be open pans, wetted papers or cloths or porus-porcelain pieces. Porus-porcelain atmometer are either cylindrical spheres or Bellani plate type (Livingston, 1915, 1935). Valveless soil moisture deficit indicator is another type which is rather simple and can be easily operated (Winter, 1963). These soil moisture deficit indicators completely eliminate laborious soil sampling, laboratory tests and complex calibrations.

It is observed that there is a reasonably good correlation between the water losses from atmometer and from irrigated vegetation (Robertson and Holmes, 1958). A fairly good correlation has been found between computed reference ET by the Penman method and the evaporation from the modified atmometer (Altenhofen and King, 1985).

The deficit indicated by the Winter's soil moisture deficit indicator was satisfactorily related to the cumulative soil moisture deficit estimated from meteorological records (Winter, 1963).

Wastage of irrigation water is a serious problem in the dry zone of Sri Lanka. More than 50% of the irrigable land could not be cultivated during the last few *Yala* seasons mainly due to scarcity of water, which occurred as a result of water wastage during the preceding *Maha* seasons. Some farmers are relying on their own water supply by constructing large diameter shallow "agro wells" in order to cultivate during both seasons. Pumps are being used to abstract water from these wells to irrigate the crops. These wells are becoming very popular in the dryzone and will continue to be so in years to come. The need to save water in their wells and the fuel cost for pumping may definitely encourage these group of farmers to use an irrigation scheduling method. Therefore, it is important to introduce a simple, low cost and yet a reliable indicator, so that the average farmer could easily afford it and use it with minimum instruction. Hence, this study was conducted to develop and test a low cost soil moisture deficit indicator for irrigation scheduling.

MATERIALS AND METHODS

Construction and operation of irrigation scheduling meter

The irrigation scheduling meter constructed for this study was a slight modification of a Winter's moisture meter (Winter, 1963) which was originally named as valveless soil moisture deficit indicator. The constructed meter consists of, a) an inner cylinder, b) an outer cylinder, c) a water receiving funnel, d) fibre wick, e) gauge glass, f) a drainage tube with a stopper and, g) a circular wooden block (Figure 1). A metal stand was constructed to keep the meter at the same level where a standard raingauge is installed.

The indicator was originally constructed with metal. Corrosion of inner and outer cylinders proved to be a serious problem during the subsequent field testing. Hence PVC pipes of 2 mm and 5 mm thickness were used to construct inner and outer cylinders respectively. The water receiving funnel is made of a metal sheet (gauge 18). Base of the outer cylinder was sealed at the bottom with a 5 mm thick PVC

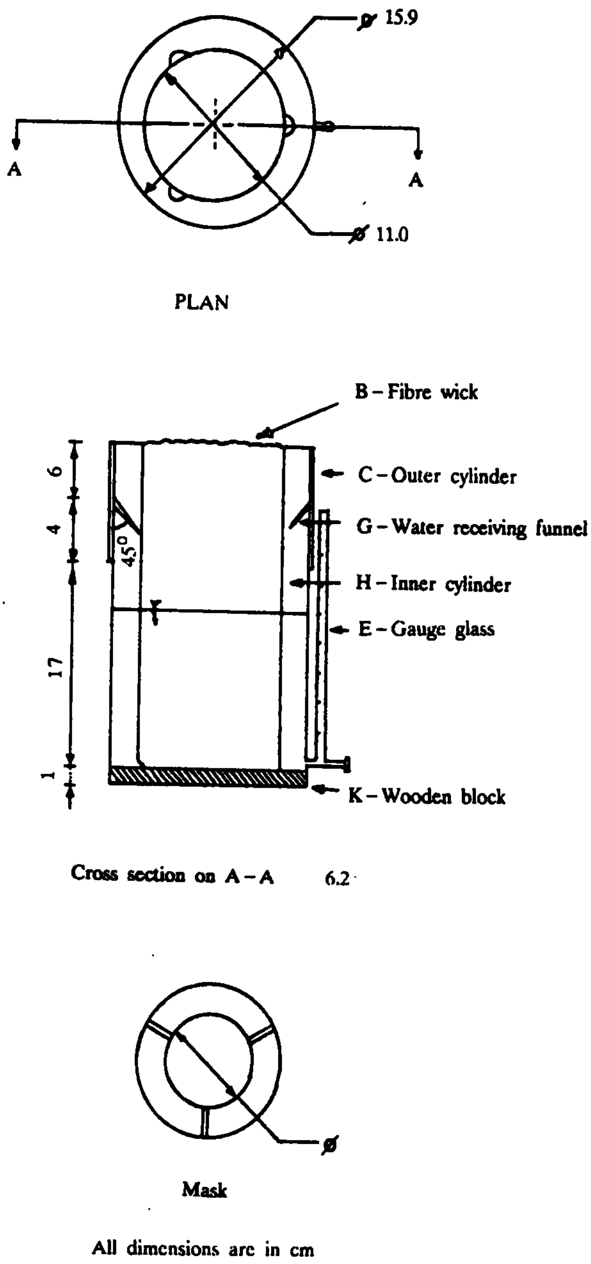


Figure 1. Irrigation scheduling indicator.

sheet to avoid leakage of water. The inner cylinder was compacted with a Jute fibre wick having a wick density of 0.35 g cm^{-3}. The Jute fibre used here, was treated with boiling water prior to compaction in the inner cylinder to kill the microbes which would otherwise be responsible for the rooting of the wick. During the hot water treatment the wick was kept for 60 minutes in a hot water bath, washed in another boiling water bath and dried in the air. A circular PVC sheet with the diameter of 6.2 cm was used to mask the evaporative surface of the fibre wick.

The evaporative surface located within the inner cylinder draws water by capillarity directly from the reservoir base. The evaporating surface allows incoming water drops to penetrate freely giving maximum splash so that all water falling into the receiver funnel area is collected. Soil moisture status is indicated by the gauge tube which was connected to the receiver reservoir. The net amount of water evaporated from the instrument and, hence, the soil moisture deficit as indicated by the depth of water level from the top of the gauge glass, can be adjusted by changing the effective area of evaporating surface by means of the mask.

This indicator should be sited according to the same rules as for a standard rain gauge and filled to a predetermined level with water when the surrounding field is at field capacity. The drop in the water level in the gauge glass shows the amount of water evaporated from the indicator. When the water level reaches the critical level marked in the gauge tube, for a given crop, the crop should be irrigated.

Method

As a preliminary stage of a long term study, five irrigation scheduling indicators were constructed at the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya. These five indicators were tested at the Makandura Agricultural Research Station in the North Western Province in Sri Lanka (latitude 7° 21", longitude 80°). Mini basins are a frequent occurrence within this agro-ecological zone of DL1. These mini basins occupy 30-40% of the valleys and other similar land units which are developed for paddy. Soil found in the basins is mainly an alluvium which is surrounded by undulating flat land cultivated with coconut. The soil on highland is a moderately drained red yellow podzolic soil. Total annual rainfall of the study area varies from 1249 to 2195 mm and follows a bimodal rainfall pattern.

The indicator evaporation data was compared with three standard methods in this study, such as, a) free water evaporation from a standard USWB class. A pan evaporimeter, b) reference crop ET estimated from the Penman method, and, c) potential ET of a well watered, disease free, well fertilized grass (*Brachiaria ruziziensis* was used as the standard grass in this study) grown to a height of 15 – 20 cm in a surface area of 1 m^2 Thornthwaite type drainage lysimeter.

Data collection

The data were recorded daily for all four methods simultaneously for a period of 7 weeks starting from 21st August 1991. To measure the indicator water deficit, all five indicators were filled with water up to the zero level and allowed to evaporate. Daily water deficit by each indicator was measured in millimeters. Standard mask having the diameter of 62 mm is used to cover the evaporative surface of the fibre wick.

The grass grown in the lysimeter was kept without any water shortage by adding a constant amount of water to the lysimeter. The difference between what was added and the amount collected as drainage water was taken as the reference ET of the respective day.

The climatological information from the meteorological station at the Agricultural Research Station, Makandura was used to compute ET by the Penman method. The computer programme CROPWAT 5.3 (FAO, 1988) was used for computations. Pan evaporation data was also collected from the same station.

RESULTS AND DISCUSSION

Figure 2 shows the variation of water deficit in 5 day intervals. The five days intervals are taken since soil moisture reaches critical level from the field capacity after such time, on average. Also, the errors of daily observation may invariably show a scatter which will obscure patterns, if any. The Figure 3 shows that all the indicators behave in

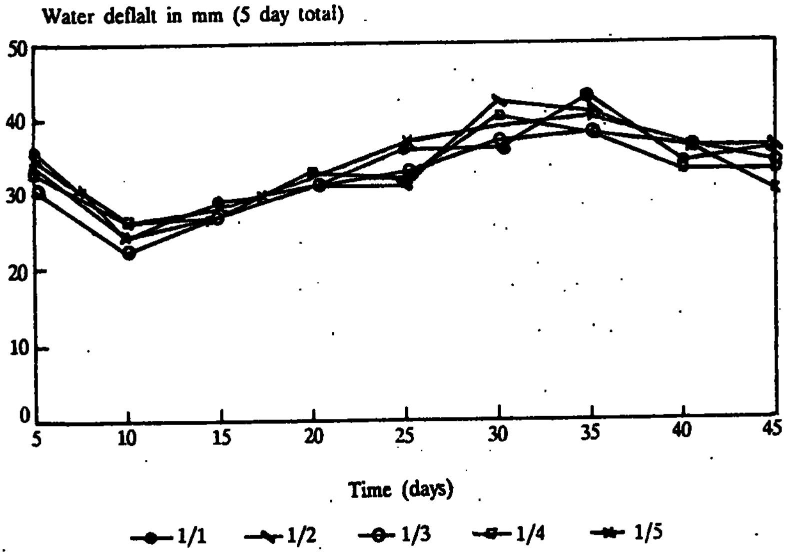


Figure 2. Water deficit by indicators in five day intervals

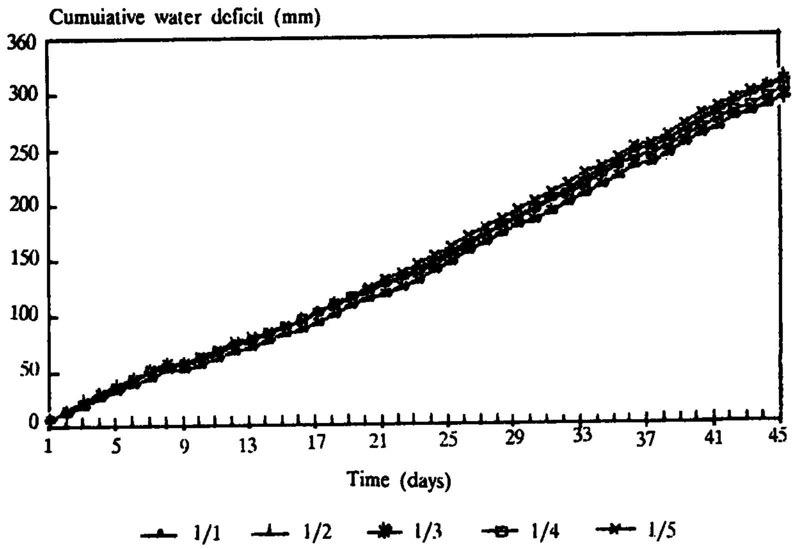


Figure 3. Cumulative water deficit by five standard indicators

a similar pattern responding to the climatic demand. This variation is unavoidable due to the robustness of constructing the indicators. Each of these indicators was hand made and there may be variations since precision cannot be guaranteed in such processes. Large differences among indicators were caused when inserting and compacting the jute fibre within the inner cylinder. Even though the wick density of 0.35 gms/cm^3 was maintained, achieving the uniformity of thread arrangement inside the wick was impossible. The cumulative water deficit for each indicator is shown in Figure 3. After 46 days from the commencement of data collection, the cumulative values of each indicator changed within +5% or −5%. This accuracy is acceptable considering the efficiency of surface water application methods which stands at 50−60%.

The comparison of pan evaporation, reference ET from lysimeter and Penman methods with cumulative indicator evaporation are shown in Figure 4. The results showed that the pan evaporation method can be used as a more reliable method for estimating reference crop ET since it runs along the reference ET from lysimeter, which is considered as the standard method for calibrating the other methods (Doorenbos and Pruitt, 1977). This also shows that the pan coefficient to be adopted for the Makandura (NWP) area to be equal to one (1.0).

The results also showed that cumulative ET from the Penman method over estimated reference crop evapo−transpiration by about 25%. In Sri Lanka, the Penman method was used extensively and preferred by many to estimate reference crop ET. The pan evaporation values have been used very rarely, and even on such occasions, a pan coefficient of 0.7 − 0.8, taken from text books, was used. The findings from this study suggest that the methods adopted to estimate reference crop ET in Sri Lanka need to be reviewed.

Figure 5 shows the regression analysis of 5 days interval values of cumulative mean indicator evaporation versus the other three methods. The correlation coefficient of 0.99 with three comparative methods has shown that the indicator can be used as a reliable instrument to measure evaporation/ET. The coefficient given in equation can be used to convert the indicator evaporation to estimate the evaporation/ET values from other methods.

In this study a circular PVC sheet of the diameter of 62 mm was used to mask the evaporative surface of the fibre wick. The evaporation

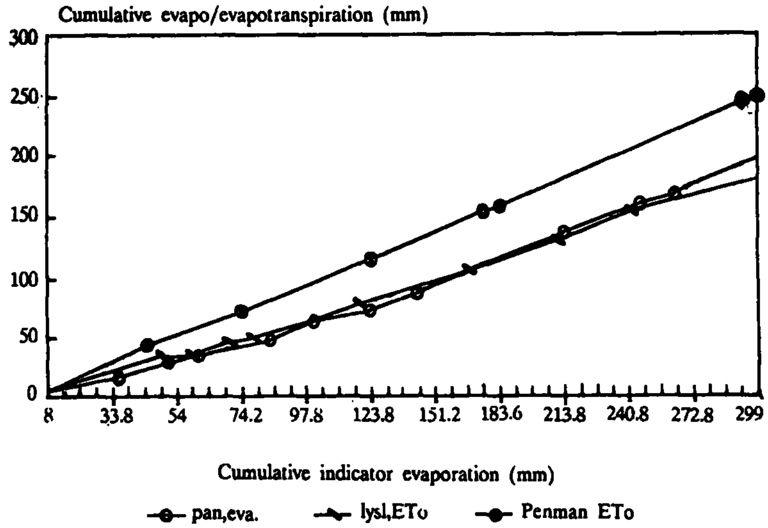
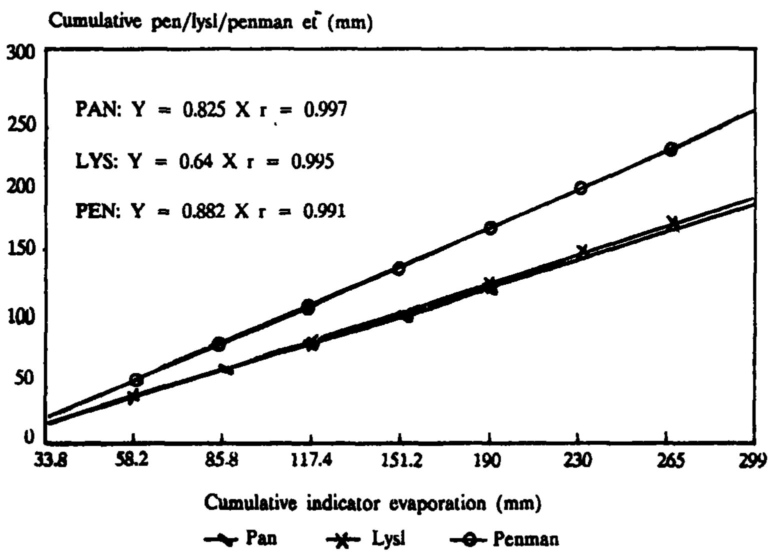


Figure 4. Comparision of different methods of estimating evapo/evapotranspiration



(in five day intervals)

Figure 5. Relationship between mean indicator evaporation and pan,lysl,and penman evapotranspiration

from the indicator could be further reduced to match the reference crop ET from the lysimeter method by increasing the diameter of the mask thus reducing the evaporative surface.

CONCLUSIONS

The results from this study have shown that the moisture indicator can be used for irrigation scheduling as a reliable technique. The comparative study of different methods indicated that pan evaporation is much more reliable than the Penman method in estimating reference crop ET, while the latter overestimated it substantially.

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