Field evaluation of drainage, actual evapotranspiration and capillary rise using Time Domain Reflectometry (TDR) under growing corn

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For a long time the sandy upland soils of northeast Thailand have been regarded as infertile because of their poor exchange properties and low nutrient content. However, recent studies have proved that soil compaction is also a major problem, as it prevents the roots from extending more than 30 cm in depth. The climate is characterised by a long dry season (October to April) and several dry spells during the rainy season (May to September). Field observations did not reveal any water logging of the soil, even a few hours after heavy downpours. We hypothesised that the compact layer (between 20 and 40 cm depth) was a major constraint for root growth and subsoil water use but not for drainage or capillary rise. In order to test these hypotheses under a growing crop, an experiment was carried out at Korat Experimental Station (15°N, 102°E) where the soil has low nutrient status and a compact layer .

The experiment monitored the variations of the total soil water content and the hydraulic head profiles for four months under growing corn. A Time Domain Reflectometry (TDR) system (TRASE BE, Soilmoisture corp.) equipped with a multiplexer was used to measure the soil water content every 30 minutes. Twelve waveguides were installed vertically in a 9-m^2 plot (at 0-10, 10-20, 20-30, 30-45, 45-60 and 60-90 cm depths). Field calibration used the gravimetric method. Two sets of tensiometers (at 10, 20, 30, 45, 60 and 90 cm depths) were installed in the same plot and monitored twice a day using a pressure transducer (SDEC system) to determine the hydraulic head. A Campbell automatic meteorological station recorded the amount of rain every five minutes and determined the parameters needed to calculate Penman potential evapotranspiration. After harvest, bulk density was measured in the plot using the cylinder method (110 cm^3); the root system of the corn was described using the grid method .

A simple water balance was used: *Total soil water content change = Rain + Capillary rise - Drainage - Actual Evapotranspiration*

The data were split between day (6 a.m. to 6 p.m.) and night values. Using the meteorological data we demonstrated that from 6 p.m. to 6 a.m. the actual evapotranspiration was insignificant due to zero solar radiation, low wind speed (< 0.2 $m.s^{-1}$), and high relative humidity (around 90%). The change in total soil water was calculated for each 12-hour period. Initially, only night data were used.

TDR results and hydraulic head profiles highlighted four periods of water flow with time. A drainage period occurred for a few days after rainfall, when the soil water content decreased during the night. Then, a zero drainage and zero capillary rise period followed for two days when the soil water content remained constant during the night. Then a capillary rise period appeared and lasted, sometimes for several weeks, when the soil water content increased during the night. We used this suite of data to calculate the soil water content changes induced by drainage and capillary rise in the different layers. Capillary rise stopped when the soil volumetric water content decreased to about 0.04 $m^3.m^{-3}$ in the topsoil, probably when the capillary link broke.

During the zero drainage and zero capillary rise period, we considered that the decrease in soil water content in the first 30 cm during the day was the actual evapotranspiration (as the root

system was confined to the first 30 cm). Cultural coefficients were calculated from the daily actual evapotranspiration values and daily Penman potential evapotranspiration values. Then, using Penman potential evapotranspiration values and the cultural coefficients at the different physiological stages of the crop, we estimated the actual evapotranspiration for the whole cycle. To make this estimation, we used the water balance during the day (6 a.m. to 6 p.m.), taking drainage fluxes and capillary rise into account.

The Time Domain Reflectometry system, thanks to a short monitoring period, permitted us to quantify in the field, under a growing plant, drainage, capillary rise and actual evapotranspiration. Drainage values, root description and bulk density determinations confirmed the hypothesis that the compact layer is an obstacle to root penetration but not to infiltration. The unsaturated conductivity of the different layers showed that even the average heaviest yearly downpour (80 mm) was completely drained in less than three days, with most of the infiltration occurring in the first five hours. Capillary rise (between 1 and 3 mm per day) made a large contribution to plant water use, despite the poor rooting depth, until about 0.04 m^3 m^{-3} of volumetric water content; then the plant died. This observation changed our approach to plant available water and root extraction close to compact layers. It is probable that poor plant growth not only resulted from plant water stress but also, to a great extent, from nutrient deficiencies or toxicity.

Keywords : Drainage, Actual evapotranspiration, Capillary rise, TDR, Sandy soil, Corn.