# Spatial and temporal Plant Water Use and Rain Inputs as Affected by Citrus Canopy and Microsprinkler Irrigation System

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## Abstract

Citrus root systems are exposed to different hydrologic conditions as a result of tree canopy shading and under-tree microirrigation. The objective of this study was to investigate shading and irrigation effects on spatio-temporal distribution of rain, plant water uptake and water content (WC) under mature Hamlin orange trees grown in a Florida sand soil. Soil WC was monitored every 30 minute in a 3 dimensional-grid system 11 m long by 3 m wide and 1.5 m deep. Weather data were monitored under and outside citrus canopies. Microirrigation, rain and weather data were used to calculate different water balance components, i.e. rain, plant water uptake and deep percolation. Rain was affected by the tree canopy interception which accounted for over 30% of the incoming rain. Plant water uptake was higher under tree canopy than in the row-middle especially during the dry season.

## Introduction

In recent decades water resource management within Florida is becoming an important function as a result of increase urban water use and year-to-year variations in rainfall. Florida receives an average of 53 inches of rainfall each year (Geraghty, 1973). Total annual rainfall for Florida may vary considerably from one part of the state to another, from one season of the year to another, and from one year to the next. Seasonal variations in rainfall are evident. Traditionally, summer is the wettest season in Florida, with 70 percent of the annual rainfall occurring during the period from May to October (*Florida's Water: A Shared Resource*, 1977).

Effective rainfall (ER) is defined as useful or utilizable rainfall. Some of the ER may be unavoidably lost due to the combined effect of rainfall intensity, frequency, and amount. Just as total rainfall varies, so does the amount of effective rainfall. The useful portion of rainfall is stored and supplied to the plant for its use.

Before reaching the soil surface, some or all of the rain may be intercepted by the canopy of the citrus tree and/or weed species covering the row middles. This fraction of rain needs to be considered in any rainfall calculation. With ridge soils, most of the water reaching the soil surface infiltrates into the soil without any significant runoff losses. Of the water that infiltrates into the soil, some may be retained and is thus stored in the root zone while the rest may move below the root zone. The water stored in the root zone is utilized for evapotranspiration. Water may be lost beyond the root zone by deep percolation to groundwater storage or a nearby surface water body, i.e., stream or lake. In summary, ER is considered to be that portion of the total rainfall that directly satisfies crop water needs.

Several methods have been used to calculate ER. Technical Release No. 21 (TR-21) has been used worldwide to calculate effective rainfall and predict irrigation requirements. Improvement in real-time soil water monitoring sensors provided a good opportunity to test the accuracy of the TR-21 in estimating ER. Obreza and Pitts (2002) used a spreadsheet to develop an analytical model that implements the TR-21 equation to calculate ER.

Little is known about the different water balance components of a central Florida citrus grove. The main objective of the current work is to use a water balance model and real-time soil water content data to investigate spatial and temporal distribution plant water uptake and effective rainfall. Specific objectives are: i) use a water balance model and real-time soil water content data to calculate and estimate effective rainfall, plant water uptake and excess water losses below the rootzone; and iii) compare the performance of the TR-21 in estimating ER with that calculated using the soil water balance model.

## Materials and Methods

Field experiments were conducted under mature Hamlin orange trees grown in a Candler fine sand (hyperthermic, uncoated, Typic Quartzipsamments). Two multiple sensor capacitance probe EnviroSCAN systems were used to monitor the soil water contents under the trees in three directions (North, South, and West of the trunk), at three locations (3, 6, and 10 feet away from the trunk) and at 4, 8, 16, and 32 inches below the soil surface. Rain gauges were installed under and outside the canopy between two adjacent tree rows close to the EnviroSCAN probes.

## Results and Discussion

### Rainfall, Evapotranspiration, and Water Content Monitoring

This period covers October to December 2001, which is part of the fall-winter dry season. The total rainfall that occurred during this period was 2.2 in (Fig. 1), which represents 4.3% of this year's total rainfall (48.1 in). During the same period, there was 8.2 in of reference evapotranspiration calculated based on weather data collected at this location. If we assume that the citrus tree met this evapotranspiration, the difference between rainfall and evapotranspiration is equal to a deficit of 6 in. This deficit was covered by irrigation only under the tree canopy portion of the grove. Irrigation accounted for 8 in. Cumulative rain and irrigation during this time period is shown in Fig. 1. Individual rainfall and irrigation events are shown in Fig. 1. Cumulative reference ETo and daily ETo are shown in Fig. 1.

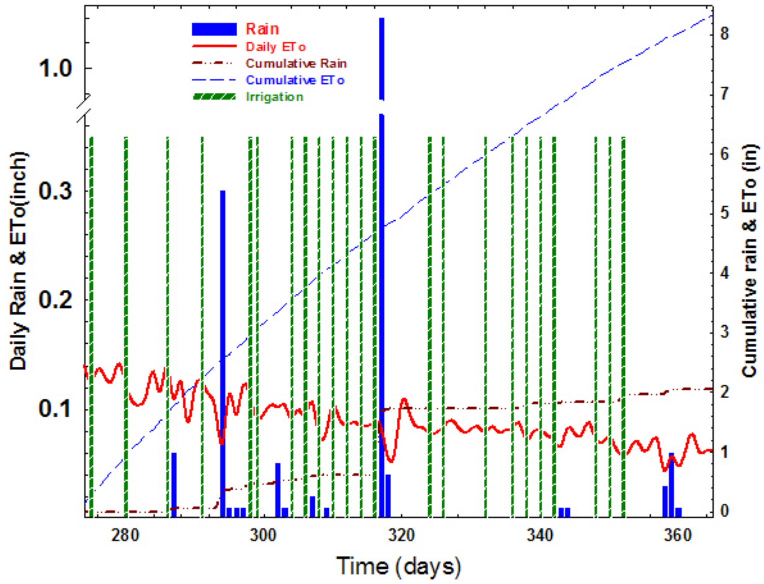


**Figure 1**

Soil water content in the top 36 inches of the soil profile was measured at three locations (under the canopy, at the canopy drip line, and in the row middle) and is shown in Fig. 2. During this period, water content level in the three different locations was the highest near the trunk under the canopy followed by that at the drip line. However, the row middle had the lowest water content because it did not receive any irrigation water (Fig. 2). The row middle location showed extended dry periods before and after the mid-November rainfall event.

Irrigation events gave a dynamic behavior of the water content under the tree canopy during the dry periods (Fig. 2). The water content for the top 3 feet varied between 2.5 in and slightly over 3.5 in. As the dry period extended, water content was maintained between 2.5 and 3.0 in during the last portion of the month of November and entire month of December.

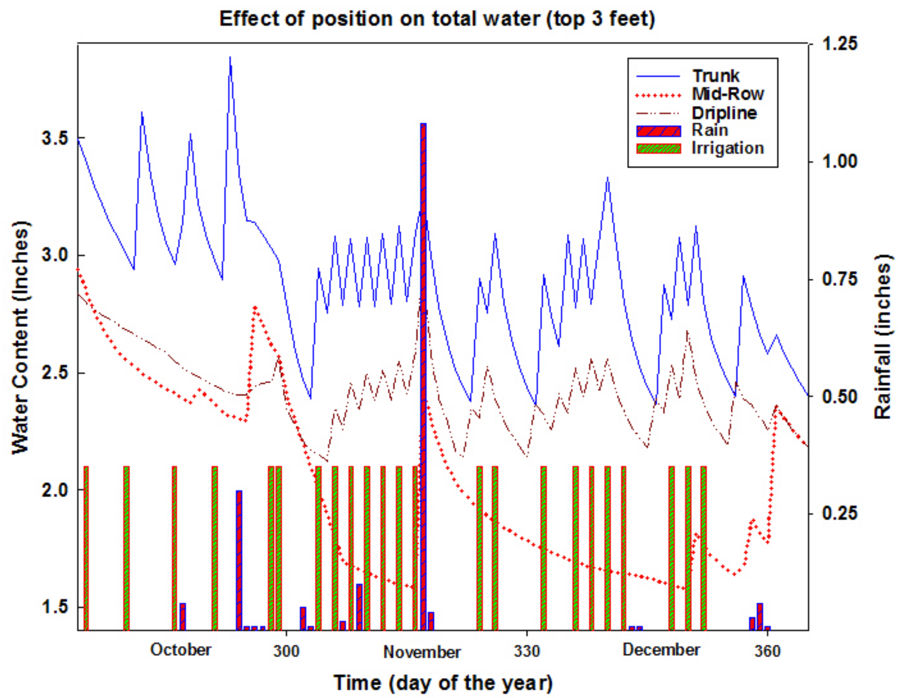


**Figure 2**

## Water Balance Model

Obreza and Pitts (2002) developed the water balance model used in this work. Detailed information about this model can be obtained from their recent publication. The input parameters for the model include: soil water holding capacity, daily irrigation duration and rainfall amount, tree spacing, rooting depth, and crop coefficient. The model calculates effective rainfall for both the irrigated and non-irrigated areas.

The first step in the modeling process was to compare the total water content in the soil profile calculated by the model using TR-21 and that measured in the field using the EnviroSCAN system. The results for the irrigated and non-irrigated portion of the soil profile are shown in Figures 6 and 7, respectively. Overall the model seems to reasonably simulate the measured field data.

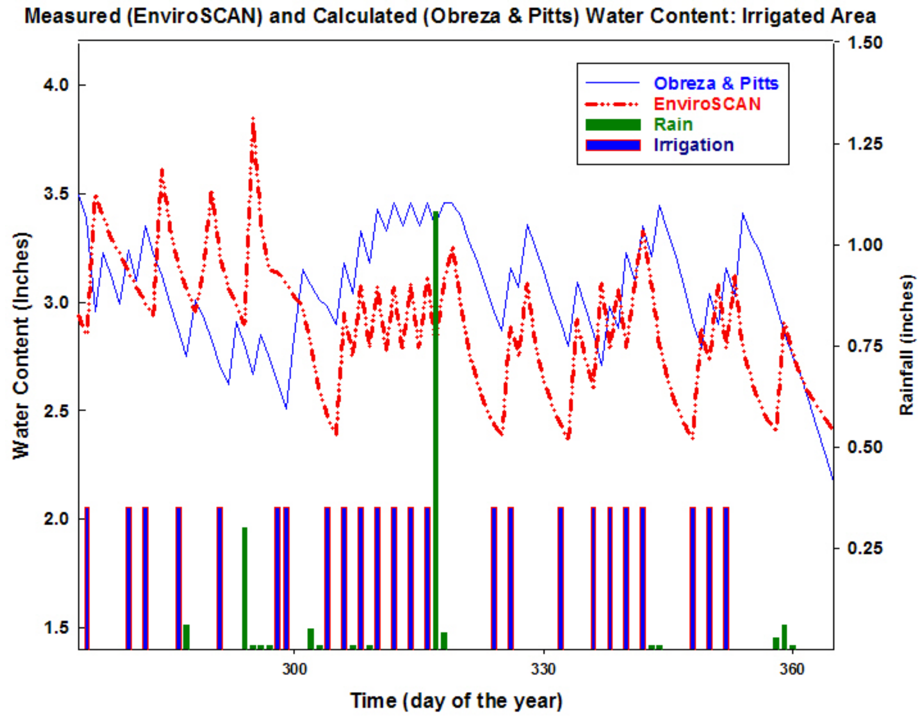


Figure 3

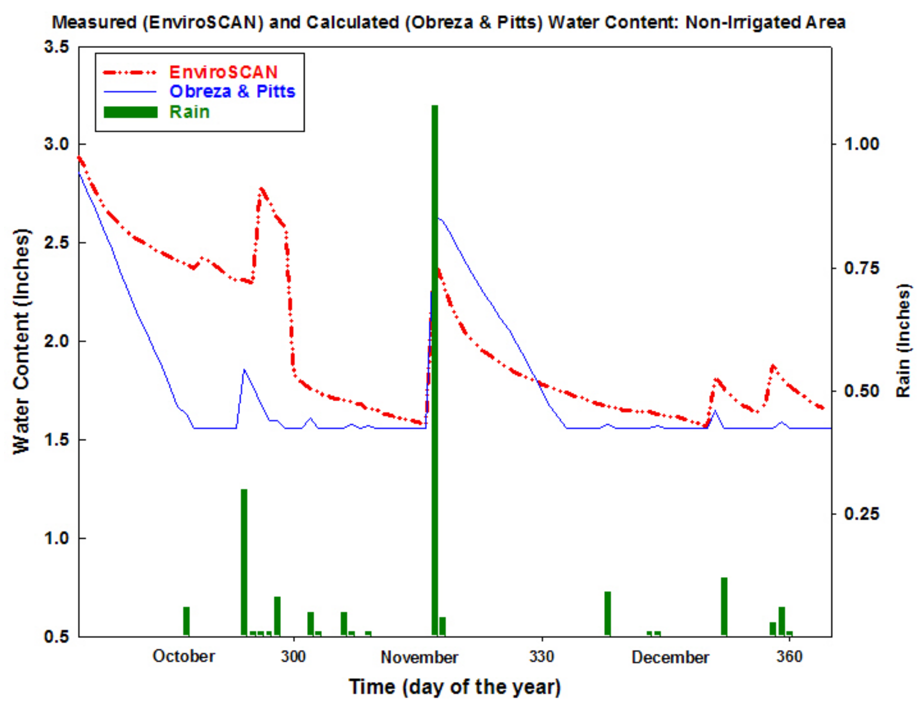


**Figure 4**

Figure 8 shows the daily and cumulative effective rainfall for the irrigated and non-irrigated areas of the grove. Effective rainfall represented 63 and 100% of the initial rainfall for the irrigated and non-irrigated areas of the grove before it hits any vegetated surface. The major factor that contributes to low effective rainfall in the irrigated area was the higher water content in this zone due to irrigation as compared to the drier row middle portion of the grove. Effective rainfall was also low under the canopy because of two other parameters that are specific to this area: irrigation and canopy interception.

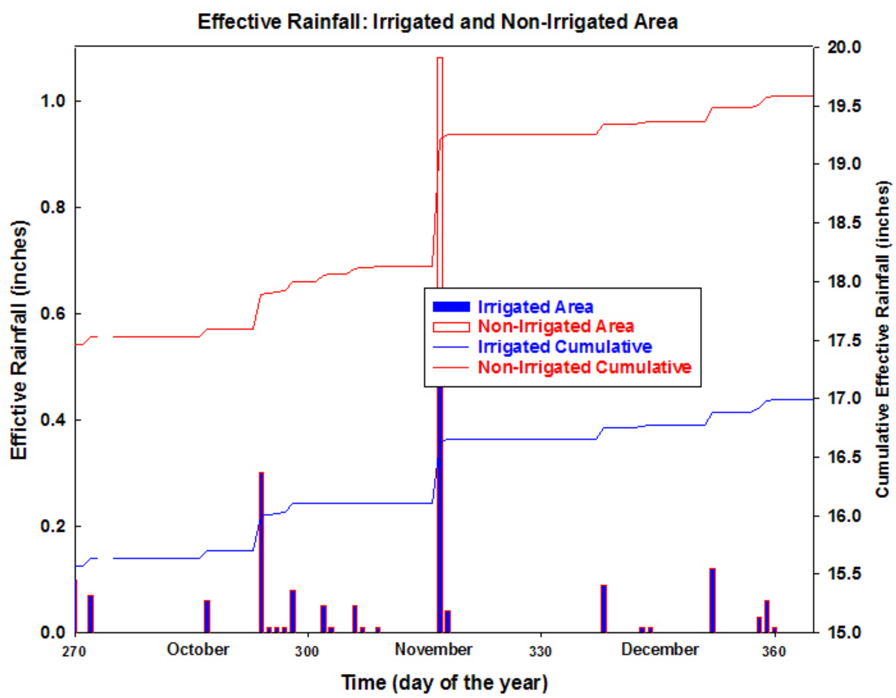


**Figure 5**

Table 1 summarizes the total monthly (in the row middle and under the canopy) rainfall, effective rainfall, and irrigation for the period of interest. This table shows that 100% of the 2.2 in of rainfall was effective in the row middle; however, it was only 63% under the tree canopy. The composite effective rainfall was 1.66 in or 77% of the total rainfall.

Table 1. Summary of the monthly, rain, irrigation, and effective rainfall (measured and calculated in the irrigated and non-irrigated areas.

| Year | Month | Total Rain (inches) | Total Irrigation wtr. appl. (gal/tree) | Monthly Meas. Irrigated Eff. Rain (inches) | Monthly Meas. Non-Irrig Eff. Rain (inches) | Monthly Meas. Comp. Eff. Rain (inches) | Monthly %actual TR-21 Eff. Rain (inches) | Monthly %actual TR-21 Eff. Rain % | Monthly %actual Meas. Eff. Rain % |
|---|---|---|---|---|---|---|---|---|---|
| 2001 | Oct | 0.53 | 174 | 0.53 | 0.53 | 0.53 | 0.27 | 52 | 100 |
| 2001 | Nov | 1.29 | 196 | 0.49 | 1.29 | 0.80 | 0.68 | 53 | 62 |
| 2001 | Dec | 0.33 | 152 | 0.33 | 0.33 | 0.33 | 0.15 | 45 | 100 |

## Summary

Most citrus groves in Florida are irrigated with microsprinklers. These systems do not wet the entire grove floor as did the earlier-used high volume overhead sprinkler systems. Hence, ER in citrus groves with microsprinkler systems is spatially and temporarily variable. The soil water status in both irrigated and nonirrigated zones was monitored in real-time. There were significant differences in water content dynamics between the irrigated and non-irrigated areas of the citrus groves. Results of three months showed that 100% of the 2.2 in of rainfall was effective in the non-irrigated area of the groves; however, only 63% was effective rainfall for the irrigated area under the tree canopy.

**References**


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