Precipitation and Drip Irrigation Effects on Soil Water Dynamics in a Semi-arid Agrosystem of Puerto Rico

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Introduction

Semi-arid regions are characterized by **low** and **erratic** rainfall, **high** temperatures, and **intense** solar radiation. Among the critical factors for plant growth are soil water content and temperature (Wang et al., 2000), and any significant shifts in these parameters can have profound effects on plant development and ecosystem stability. In these ecosystems, high year-long **evapotranspiration increases** plant **water consumption** (Modarres & Rodrigues da Silva, 2007; Rathore et al., 2019). In Puerto Rico's southern agrosystems—areas shaped by both natural and human processes—**crops rely almost entirely on drip irrigation** (Kuniansky et al. 2004). Therefore, understanding the impact of combined precipitation events and drip irrigation is crucial for **sustainable water use under climate change**.

Objective:

To investigate the **environmental effects** of drip irrigation and pulsing precipitation on soil water content in avocado crops.

Questions and Hypotheses:

1. How does the quantity, intensity, and frequency of pulsing precipitation influence the soil profile's water content?
2. Does soil type affect water availability in the agrosystem?

➢ We hypothesized that effective precipitation would have an **additive effect** on the water content of soils that depend on irrigation.

➢ Soil type will determine the **effectiveness** of precipitation in influencing soil water content.

San Antón (Sa): fine-loamy, mixed, superactive, isohyperthermic Cumulic Haplustolls

Jacaguas (Jg): loamy-skeletal, mixed, superactive, isohyperthermic Fluventic Haplustolls

Study Site

- This study is conducted at **Finca Atabey**, Santa Isabel, P.R. (17°59'46"N 66°2, 4'36" W), located in the semi-arid region of the island. (Figure 1B).
- The crop of interest is **avocado** (***Persea americana***), which is grown on two soil series on-site: Jacaguas and San Antón.

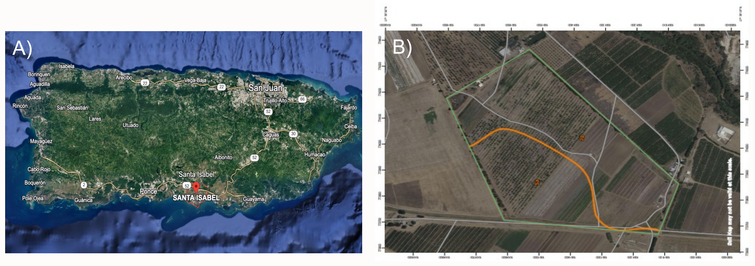


Figure 1. A) **Santa Isabel**, P.R., and B) **Finca Atabey**, located in the semi-arid region of the island.

Materials and Methods

- Meteorological data were recorded for a year using a **METER ATMOS 41W** meteorological station.
- Water content data were collected from the soils of avocado crops using **METER TEROS 12** sensors at depths of a) 0–15 cm, b) 15–30 cm, and c) 35–50 cm.
- Statistical analyses were carried out using JMP® 18 and R Studio packages.

Dry Days Equation: Rainfall (mm) – Evapotranspiration (mm)

Soil Sensors

Meteorological Station

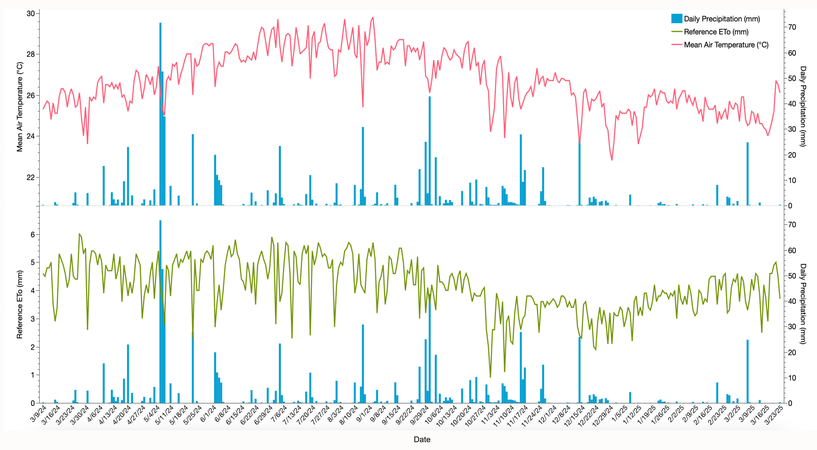
Results

Table 1. Quantity, Intensity, and Frequency of Precipitation by Month (dry days = P ≤ Et_0)

Month	Quantity (mm)	Intensity (total rainfall per day/mm)	Frequency (rainy days/month)	Dry days per month	Wet days per month
March 2024*	13.1	0.2-5.1	7	21	2
April 2024	66.9	0.02-22.9	16	25	5
May 2024	**207.8**	**0.05-71.6**	11	25	6
June 2024	63.6	0.03-19.9	13	24	6
July 2024	55.8	0.02-23.3	17	28	3
August 2024*	58.1	0.05-30.8	9	12	4
September 2024	65.0	0.05-25.0	15	25	5
October 2024	111.5	0.1-42.8	**22**	24	7
November 2024*	99.6	0.02-27.8	**22**	22	**8**
December 2024	43.1	0.05-25.8	14	27	4
January 2025	8.4	0.02-4.3	11	**30**	1
February 2025*	16.2	0.2-8.0	7	26	2
March 2025*	26.9	0.2-24.8	5	22	1
-	**Total: 836.1**	-	**Total: 169**	**Total: 311**	**Total: 54**
-	Average: 64.3	-	Average: 13	Average: 23.9	Average: 4.2
-	SD: 53	-	SD: 5.4	SD: 4.4	SD: 2.3

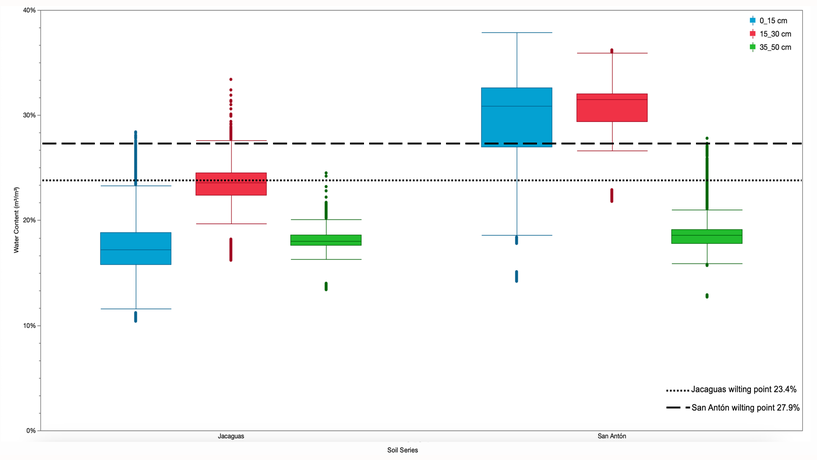
The site experiences mostly dry days. Pulsing precipitation events are the norm. Effective precipitation (P > ET_0) occurred in 54 days throughout the study period.

Figure 2. Comparison Between Daily Precipitation, Air Temperature, and Evapotranspiration over Time



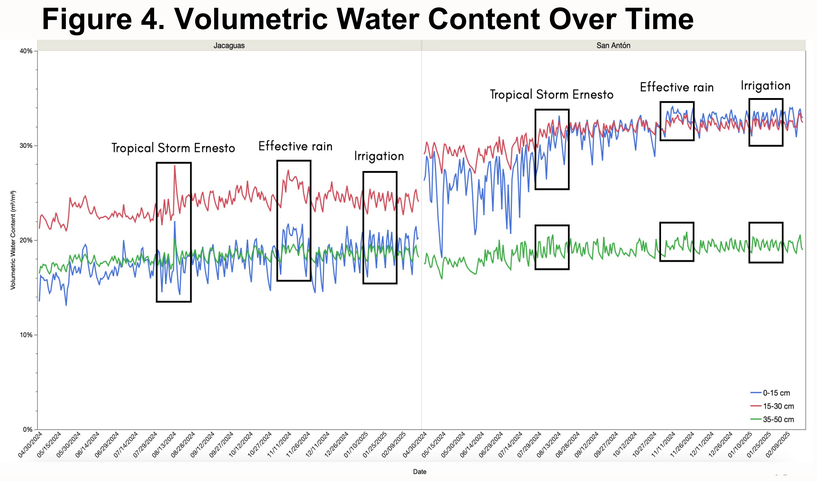
Results validate semi-arid conditions, with low cumulative precipitation, high temperatures, and high evapotranspiration.

Figure 3. Volumetric Water Content by Soil Series



Soil types vary in their ability to retain water. Soil water content at the Jacaguas site was mostly below the wilting point, except for some 15–30 cm values. In San Antón, the 35–50 cm depth had no available water, while the 0–15 cm and 15–30 cm depths exceeded the wilting point.

Figure 4. Volumetric Water Content Over Time



Significant rainfall events, such as Tropical Storm Ernesto, and effective rainfall have increased soil water content, supporting our initial hypothesis. Lastly, one-way ANOVA results indicate a significant difference between soil series and among depths (Prob > 0.0001), which confirms our second hypothesis.

Conclusions and Future Directions

- Our work incorporates ecohydrological variables to provide an **ecosystem-level approach** in a semi-arid agricultural system.
- In this place, the frequency, intensity, and timing of **brief climatic events and crop and water management** dictate the dynamics between soil and received water.
- This investigation reveals that crops in semi-arid regions **rely heavily on irrigation**, as soil water content appears to be influenced primarily during significant rainfall events.
- This underscores the need for ongoing research into the lasting impacts on **crop productivity** and resource management.
- Future studies should consider other meteorological variables impacting **water retention and availability**, such as cloud cover, lower temperatures, and lower evapotranspiration rates.
- There is very little data on soil water dynamics in the **southern agricultural region** of Puerto Rico.
- Therefore, our ongoing study will continue to provide highly relevant information for **water use and crop resilience**, especially under projected drier conditions due to climate change.

Literature Cited

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Contact