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Low-Cost Soil Moisture Sensing for Irrigation Scheduling on Smallholder Farms in Semi-Arid Jordan

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Abstract. Irrigation water is the scarcest agricultural input in semi-arid regions, yet most smallholder farmers schedule irrigation by habit rather than by measurement. We designed a capacitive soil moisture probe that costs under US$12 per unit and compared it with a laboratory-grade time-domain reflectometry (TDR) reference over one full growing season on 18 tomato plots. After a two-point soil-specific calibration the probe reached a root-mean-square error of 2.1% volumetric water content ($R^2 = 0.94$). Plots irrigated according to probe readings used 27% less water than plots irrigated on the farmers' usual calendar, with no significant loss of yield ($p = 0.31$). The results show that low-cost sensing can support evidence-based irrigation on small farms where commercial systems are unaffordable.

Keywords: soil moisture، irrigation scheduling، low-cost sensors، smallholder farming، water productivity

الاستشعار منخفض التكلفة لرطوبة التربة لجدولة الري في المزارع الصغيرة في المناطق شبه الجافة بالأردن

الملخص. تُعدّ مياه الري أندر مدخلات الزراعة في المناطق شبه الجافة، ومع ذلك يجدول معظم صغار المزارعين الري بالعادة لا بالقياس. صمّمنا مجسًّا سعويًّا لرطوبة التربة تقلّ كلفته عن 12 دولارًا للوحدة، وقارنّاه بمرجع مخبري يعتمد على قياس الانعكاس الزمني (TDR) طوال موسم زراعي كامل في 18 قطعة طماطم. وبعد معايرة نقطتين خاصة بالتربة بلغ جذر متوسط مربع الخطأ 2.1% من المحتوى الحجمي للماء ($R^2 = 0.94$). واستهلكت القطع المروية وفق قراءات المجس ماءً أقل بنسبة 27% من القطع المروية وفق جدول المزارعين المعتاد، دون فقدان معنوي في الإنتاج ($p = 0.31$). تُظهر النتائج أن الاستشعار منخفض التكلفة يدعم الري المبني على الأدلة في المزارع الصغيرة التي لا تتحمل كلفة الأنظمة التجارية.

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1. Introduction

Agriculture consumes roughly seventy percent of the freshwater withdrawn worldwide, and in semi-arid countries such as Jordan the share is even higher while renewable supplies per person are among the lowest in the world. Most smallholder farmers decide when to irrigate from habit, the appearance of the crop or a fixed calendar. Direct measurement of soil water would allow irrigation to follow crop demand (Allen et al., 1998), but commercial soil moisture systems remain too expensive for farms of one to three hectares.

In this study we ask whether a capacitive probe built from inexpensive components can be accurate enough to schedule irrigation, and whether doing so saves water without harming yield.

2. Materials and Methods

2.1 Study site and design

The experiment ran from March to August 2025 on 18 plots of drip-irrigated tomato (*Solanum lycopersicum*) in the Jordan Valley. Table 1 summarises the soils. Nine plots were irrigated according to probe readings and nine followed the farmers' usual calendar.

Table 1. Soil properties of the experimental plots

Soil class	Sand (%)	Silt (%)	Clay (%)	Plots
Sandy loam	62	24	14	6
Loam	41	38	21	7
Clay loam	33	31	36	5

2.2 Sensor and calibration

The probe measures the capacitance of the soil between two electrodes and converts it to volumetric water content. Each probe was calibrated in the field against a time-domain reflectometry (TDR) reference (Topp et al., 1980) at an air-dry and a field-capacity point.

3. Results

After calibration the probe agreed closely with the reference (RMSE = 2.1% volumetric water content, $R^2 = 0.94$, n = 1,260 paired readings). Plots irrigated by probe received 27% less water over the season than calendar plots, and marketable yield did not differ significantly ($p = 0.31$).

Table 2. Seasonal water use and yield

Treatment	Water applied (mm)	Yield (t/ha)
Calendar (farmer practice)	612	78.4
Probe-based scheduling	447	77.1

4. Discussion

The saving observed here is in line with reviews of sensor-based irrigation (Robinson et al., 2008). Sensor drift appeared late in the season in the two sandiest plots, which suggests re-calibrating once per season. The study covers one crop in one season, so the results should be confirmed on other crops and soils.

5. Conclusion

A probe costing under US$12 can support irrigation scheduling with accuracy sufficient for tomato production, saving about a quarter of the water without a measurable yield penalty. Wider adoption would require training and a simple calibration routine.

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References

1. Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements (FAO Irrigation and Drainage Paper 56). Food and Agriculture Organization of the United Nations.
2. Robinson, D. A., Campbell, C. S., Hopmans, J. W., Hornbuckle, B. K., Jones, S. B., Knight, R., Ogden, F., Selker, J., & Wendroth, O. (2008). Soil moisture measurement for ecological and hydrological watershed-scale observations: A review. Vadose Zone Journal, 7(1), 358–389. https://doi.org/10.2136/vzj2007.0143
3. Topp, G. C., Davis, J. L., & Annan, A. P. (1980). Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. Water Resources Research, 16(3), 574–582. https://doi.org/10.1029/WR016i003p00574