BIG DATA AND CLOUD PLATFORMS

From data lake to data warehouse

Context: Soil moisture monitoring

Optimizing soil moisture is crucial for watering and crop performance [1]

- **GOAL**: build an expert system to save water while improving fruit quality (i.e., provide a recommendation of the optimal amount of water)
- Soils have different water retention
- Watering systems have different behaviors (e.g., drippers and sprinklers)
- Plants have different water demand (e.g., Kiwi [2] vs Grapes)
- Sensors produce different measurements with different precisions

[1] Turkeltaub et al., Real-time monitoring of nitrate transport in the deep vadose zone under a crop field–implications for groundwater protection, Hydrology and Earth System Sciences 20 (8) (2016) 3099–3108.
[2] M. Judd, et al., Water use by sheltered kiwifruit under advective conditions, New Zealand journal of agricultural research 29 (1) (1986) 83–92.

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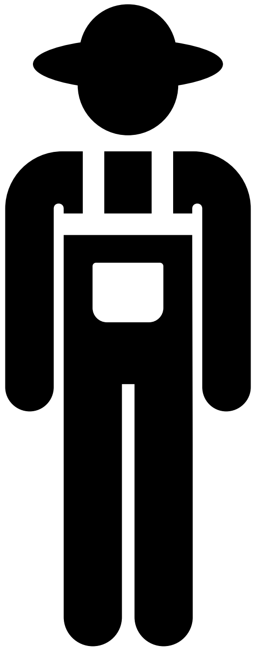

(Example) Scenarios of digital transformation in agriculture

Scenario #1

- The farmer/technician controls the watering system based only on the experience
- No digital data/KPIs/automation

Scenario #2

- The control of the watering system is refined by observing sensor data
- Sensor data is digitalized, no KPIs/automatic

Scenario #3

- Sensor data feeds a decision support system that, knowing how to optimize KPIs, controls the watering system

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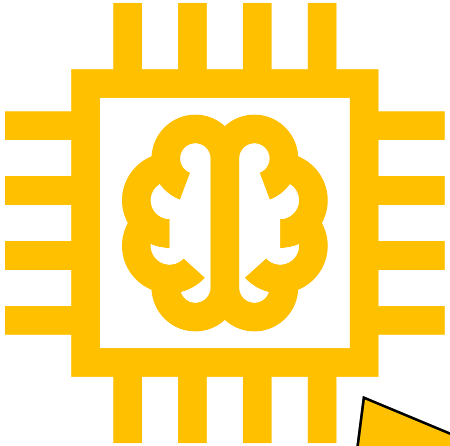

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Artificial intelligence (AI) is intelligence demonstrated by machines. AI research has been defined as the field of study of intelligent agents, which refers to any system that perceives its environment and takes actions that maximize its chance of achieving its goals.

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Context: Soil moisture monitoring

We need to understand how the soil behaves

Simulate [1, 2] the soil behavior according to physical models [3]

- However, a fine tuning is required
- We need to know/parametrize everything
  - Soil (e.g., retention curve, hysteresis [3])
  - Plant (e.g., roots, LAI)
  - Weather conditions (temperature, humidity, wind, precipitations)
  - Watering system (e.g., capacity, distance between drippers)

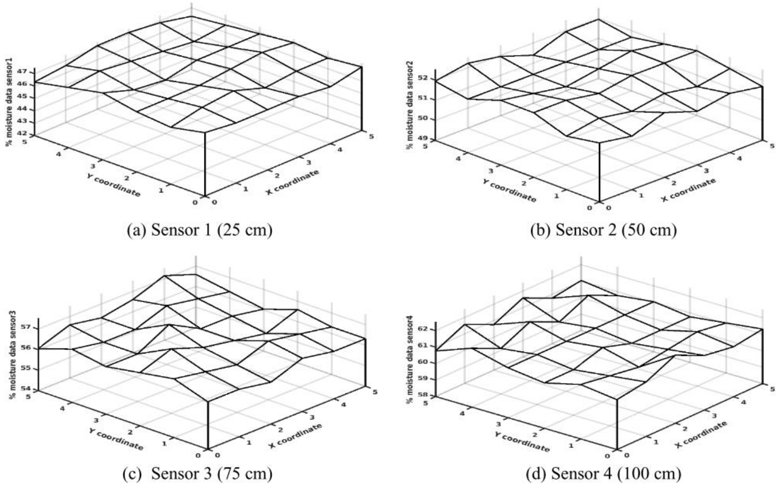
Tuning can take months (of human interactions)!

- Need to collect samples from the field… if parameters are incorrect, trace back
- Need to implement/code all these features into the simulator [1, 2]
- Hyper-parameter tuning with machine learning can help, but it is not a silver bullet

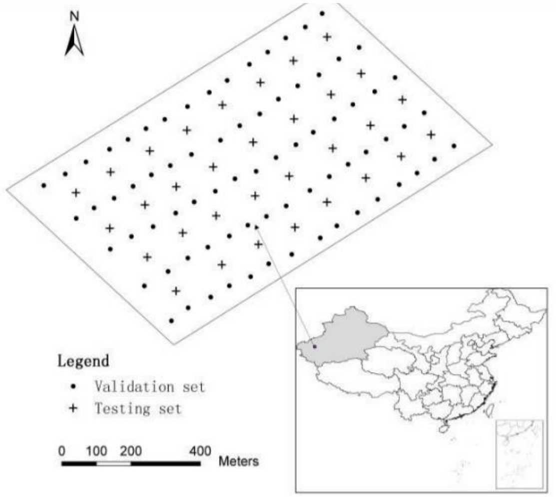
[1] Šimunek, J., et al. "HYDRUS: Model use, calibration, and validation." Transactions of the ASABE 55.4 (2012): 1263-1274.
[2] Bittelli, Marco, et al. Soil physics with Python: transport in the soil-plant-atmosphere system. OUP Oxford, 2015.
[3] Van Genuchten, M. Th. "A closed-form equation for predicting the hydraulic conductivity of unsaturated soils." Soil science society of America journal 44.5 (1980): 892-898.
[4] Pham, Hung Q., Delwyn G. Fredlund, and S. Lee Barbour. "A study of hysteresis models for soil-water characteristic curves." Canadian Geotechnical Journal 42.6 (2005): 1548-1568.

Context: Soil moisture monitoring

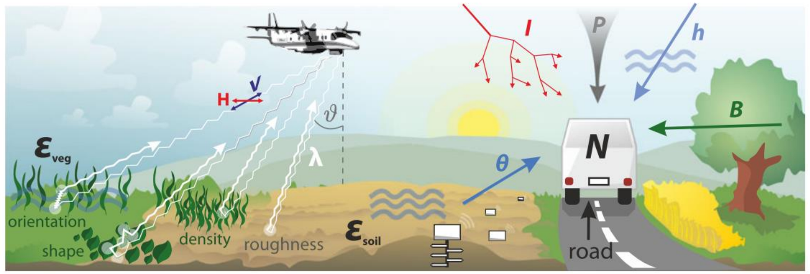
But… we have sensors!



[1]



[2]

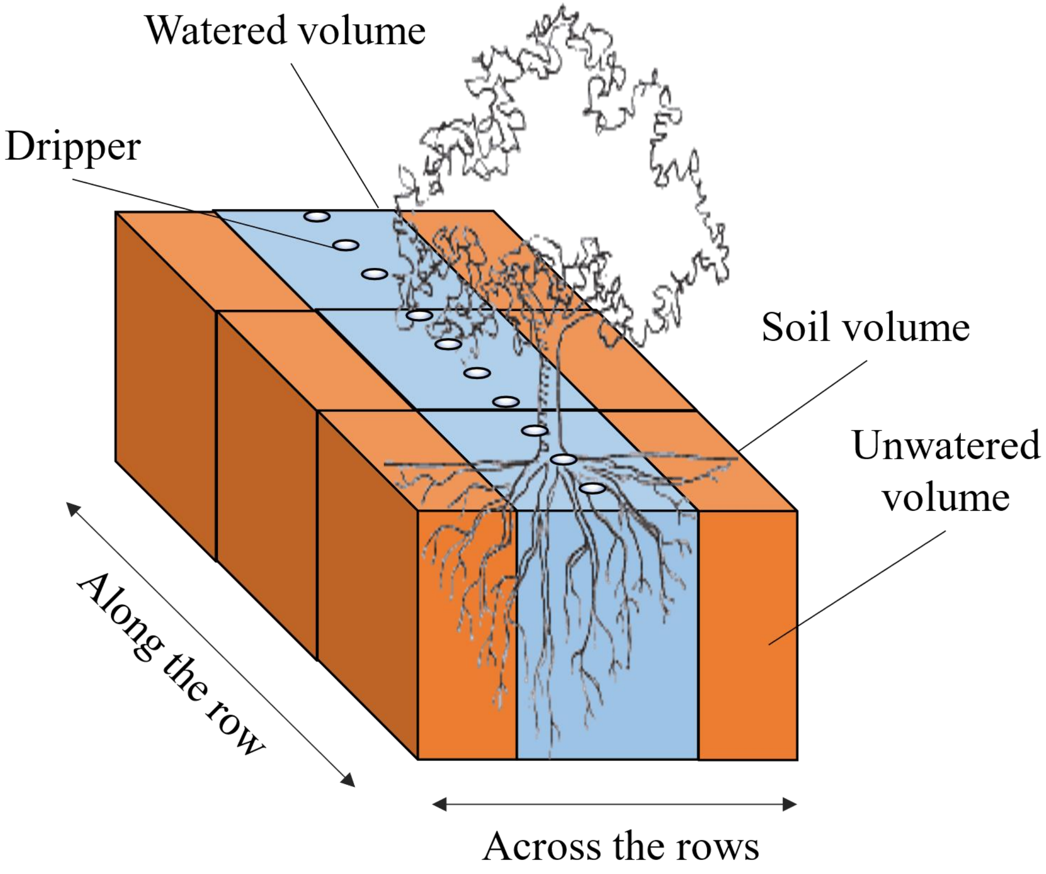


[3]

- These settings are too coarse to monitor soil moisture with precision
- They require many sensors

[1] Koyuncu, Hakan, et al. "Construction of 3D soil moisture maps in agricultural fields by using wireless sensor communication." Gazi University Journal of Science 34.1 (2021): 84-98.
[2] Zheng, Zhong, et al. "Spatial estimation of soil moisture and salinity with neural kriging." International Conference on Computer and Computing Technologies in Agriculture. Springer, Boston, MA, 2008.
[3] Fersch, Benjamin, et al. "Synergies for soil moisture retrieval across scales from airborne polarimetric SAR, cosmic ray neutron roving, and an in situ sensor network." Water Resources Research 54.11 (2018): 9364-9383.

Reference scenario



We consider an orchard where

- Kiwi plants are aligned along rows
- Each row has many drippers (e.g., 1 every meter)
- Drippers can water a limited soil volume

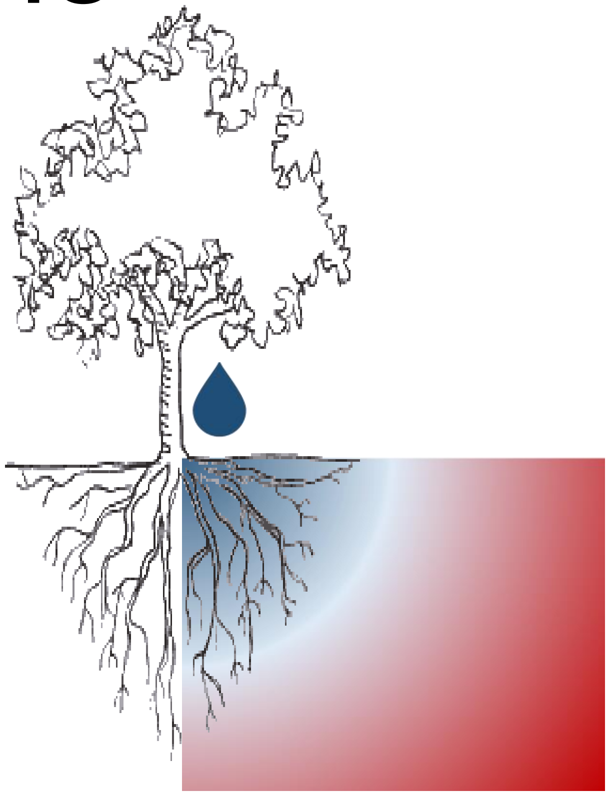
Francia, Matteo, et al. "Multi-sensor profiling for precision soil-moisture monitoring." Computers and Electronics in Agriculture 197 (2022): 106924.

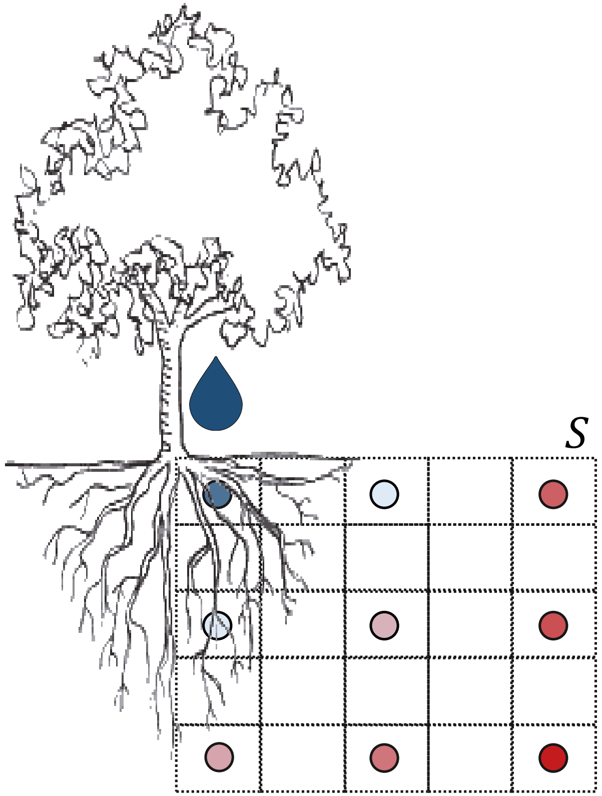
Reference scenario

(a) Soil moisture is a continuum

(b) Sensors return a discretized representation of soil moisture

- The monitoring accuracy changes
- depending on the sensor layout





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Reference scenario

We consider a 2D grid of 3 x 4 gypsum block sensors

- Sample soil moisture-sensor data every 15 minutes
- Collect dripper and weather data (humidity, temperature, solar radiation, wind) every hour

How many data does each monitored field produces every season?

- $\left(12 \cdot 4 \frac{samples}{hour} + 5 \frac{samples}{hour}\right) \cdot 24 \frac{hour}{day} \cdot 30 \frac{day}{month} \cdot 5 \frac{month}{year} \cong 200 \cdot 10^3 \frac{samples}{year}$

We monitored 6 fields for 2 years

- $200 \cdot 10^3 \frac{samples}{year} \cdot 2\ years \cdot 6 = 2.4 \cdot 10^6\ samples$

We should consider accessory data for storage and optimization structures

- In two years, we collected/generated 16GB data (as of 2022-08-30)

Francia, Matteo, et al. "Multi-sensor profiling for precision soil-moisture monitoring." Computers and Electronics in Agriculture 197 (2022): 106924.

In action