Developing a sensor-based agricultural water management system for irrigation scheduling, automation, and optimization

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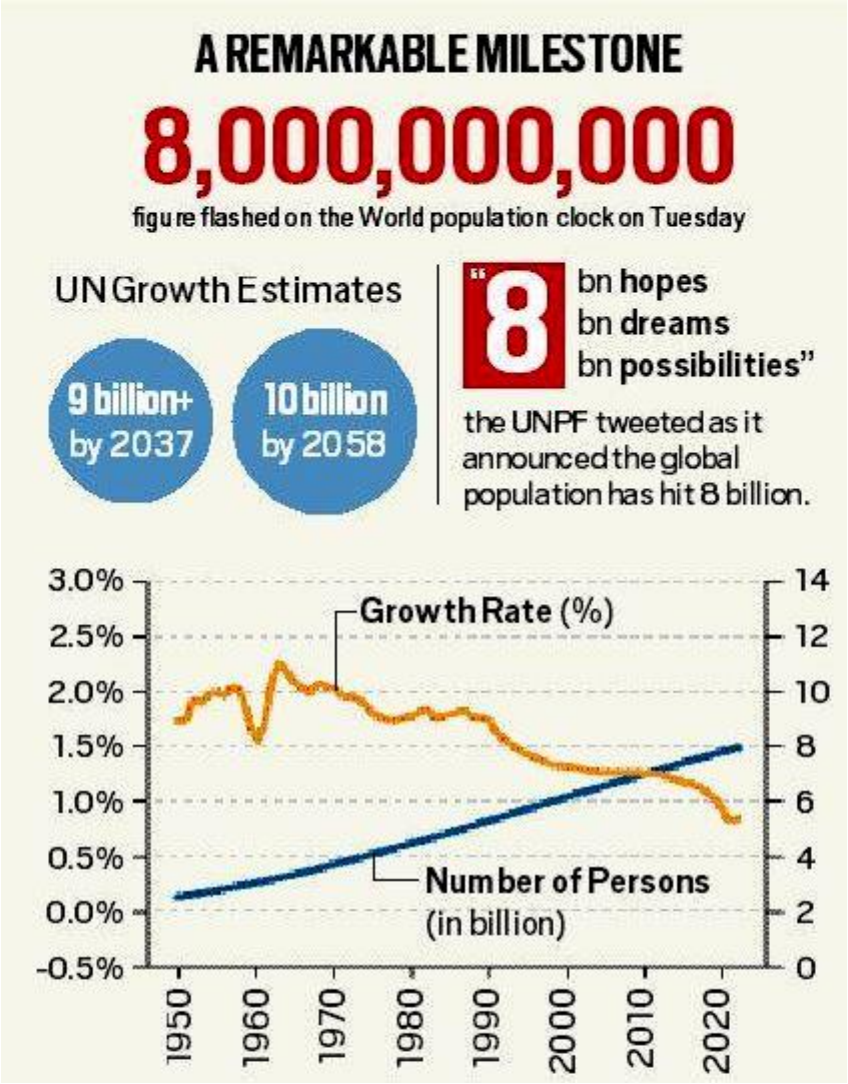
Introduction

The world population will cross 8 billion people by 2025 posing challenges to the world's:

- Global Poverty
- Environment
- Sustainable Development
- World's Food Security
- Water Availability

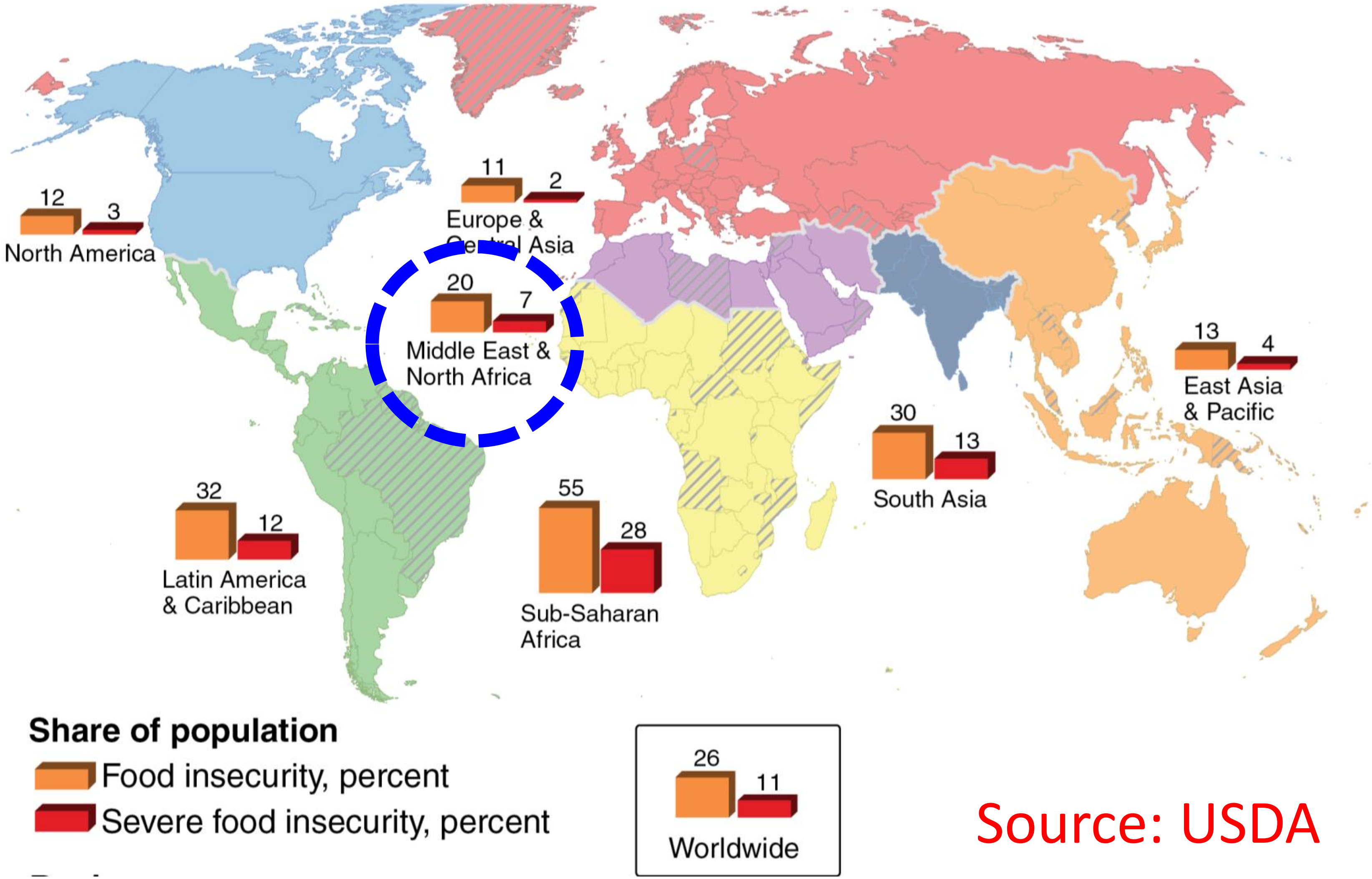


Qatar is investing in and encouraging research and development initiatives related to food security and sustainability.

Ben Hassen et al., 2020; Ungureanu et al., 2020; Guo et al., 2021

Global, GCC Gulf Cooperation Council) Food Insecurity

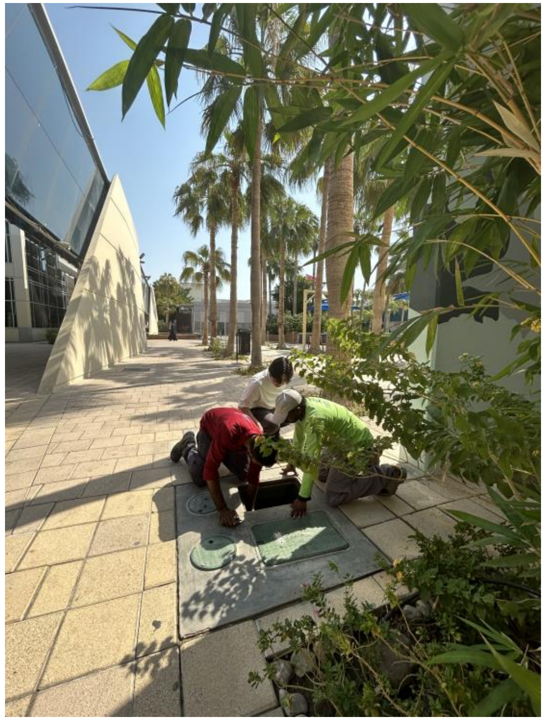
GCC members import about 85% of their food.



Source: USDA

Water is used to irrigate food plants, trees, landscape

Solenoid irrigation valves are installed but turned ON and OFF manually every day on a fixed interval basis.



To address the challenges of food security, researchers at UDST are working on water availability/management issues

Current Practice:
Interval-based irrigation
Demerits

- Ignores actual crop water needs > over irrigation > nutrient loss > poor yield
- Inefficient resource management > non-profitable farming

Proposed Method:
Sensor-based irrigation
Merits

- Considers actual crop water needs > smart irrigation > optimum yield
- Water conservation > water use efficiency > nutrient use efficiency > farm profit

Objectives

i) Investigate smart and sustainable irrigation systems for Qatar,

ii) Develop weather-based models to predict crop water requirements,

iii) Capture the real-time water content in the root zone,

iv) Conduct site-specific irrigation strategies based on crop needs, and

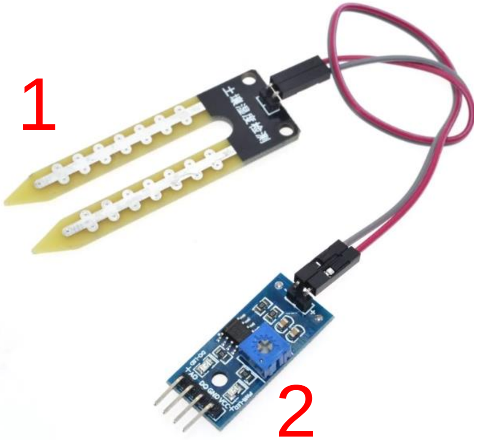
v) Evaluate water use efficiency.

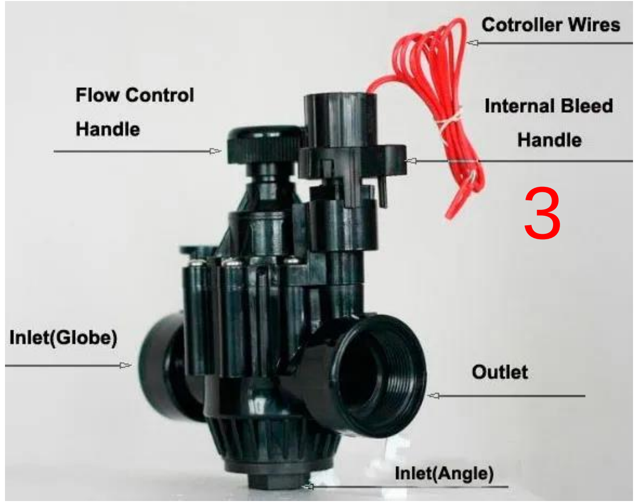
Methodology Sensor-based irrigation

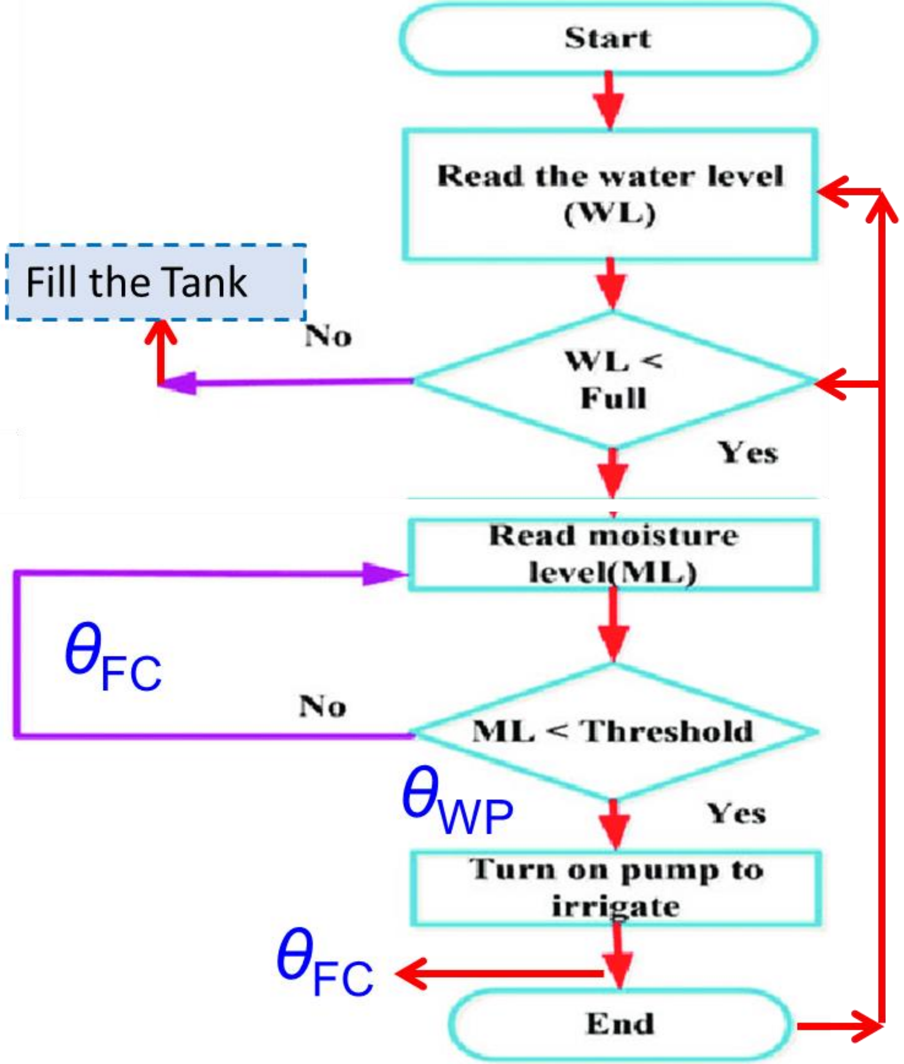
Irrigation scheduling > System Automation

1. Soil Moisture Sensor: ϑ
2. Microprocessor
3. Solenoid irrigation valve

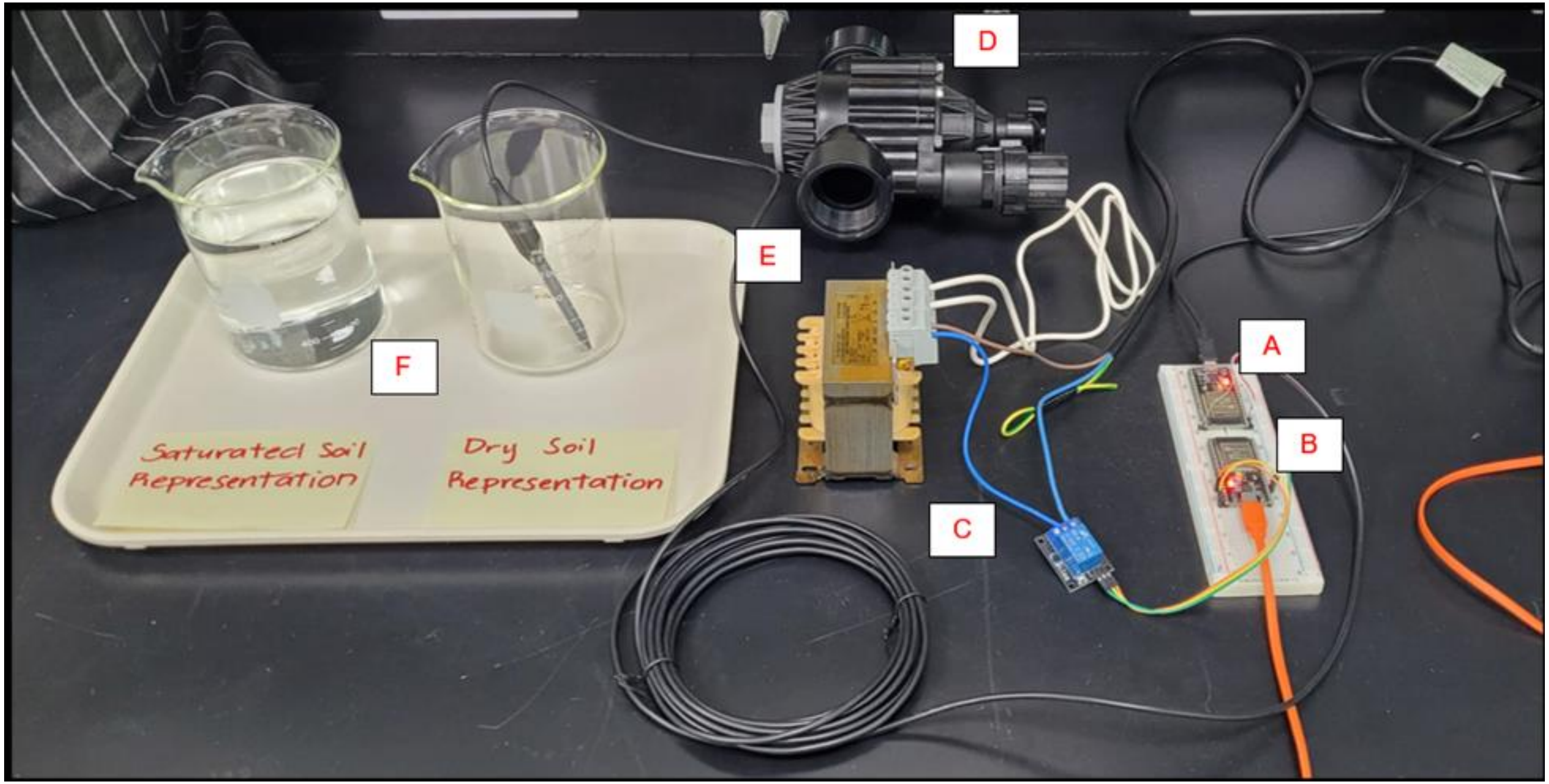
Threshold setup at ϑ_{FC} and ϑ_{WP}







Methodology



A) a wireless soil moisture sensor, (B) an irrigation solenoid valve controller, (C) a single channel relay, (D) a solenoid valve, (E) a step-down transformer 240/24VAC, and (F) soil state representations

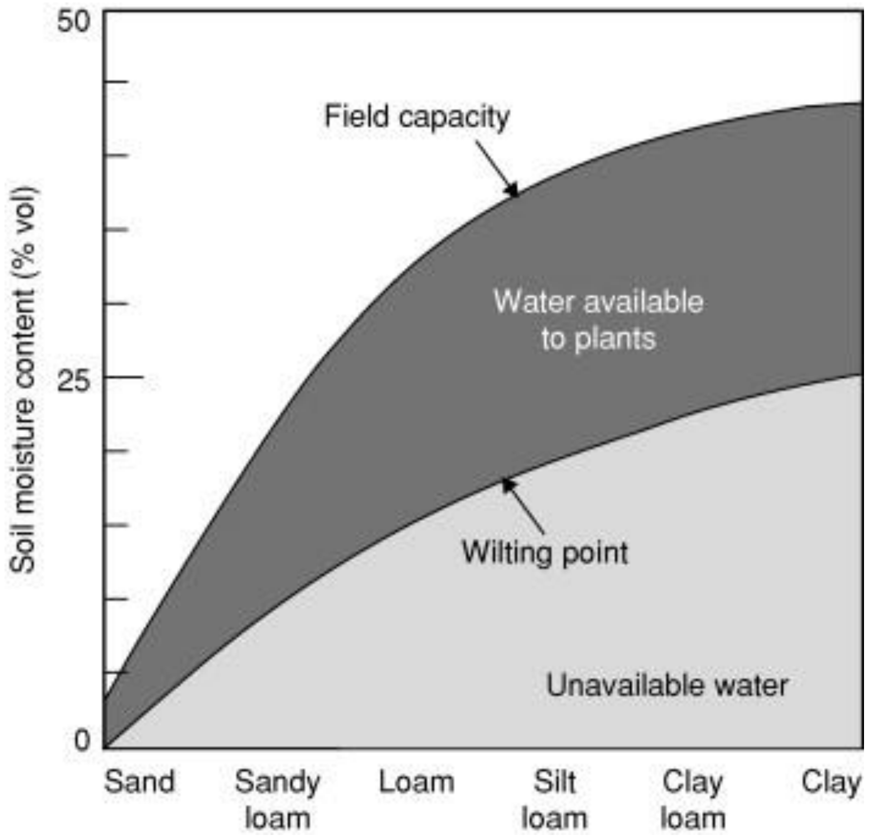
Next steps

Sensor will tell us plant available water (ϑ_{AW}) in soil.

ϑ_{AW} is water available between field capacity (ϑ_{FC}) and wilting point (ϑ_{WP}).

- $\vartheta_{AW} = \vartheta_{FC} - \vartheta_{WP}$
- WP = Plants cannot uptake water after WP
- Start of irrigation before WP
- Stop of irrigation at FC
- Find a relationship between ϑ_{FC} and ϑ_{WP}

for different soils



Next steps

Soil Sampling - Sensor Calibration

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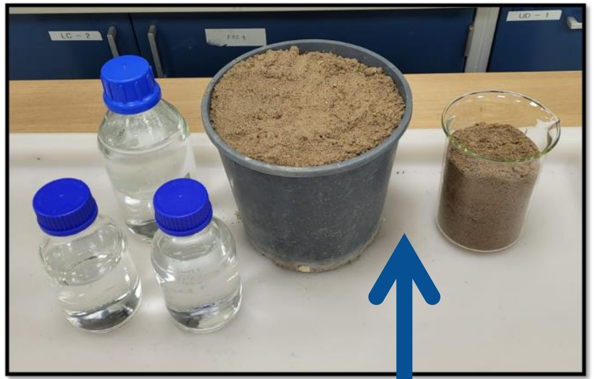


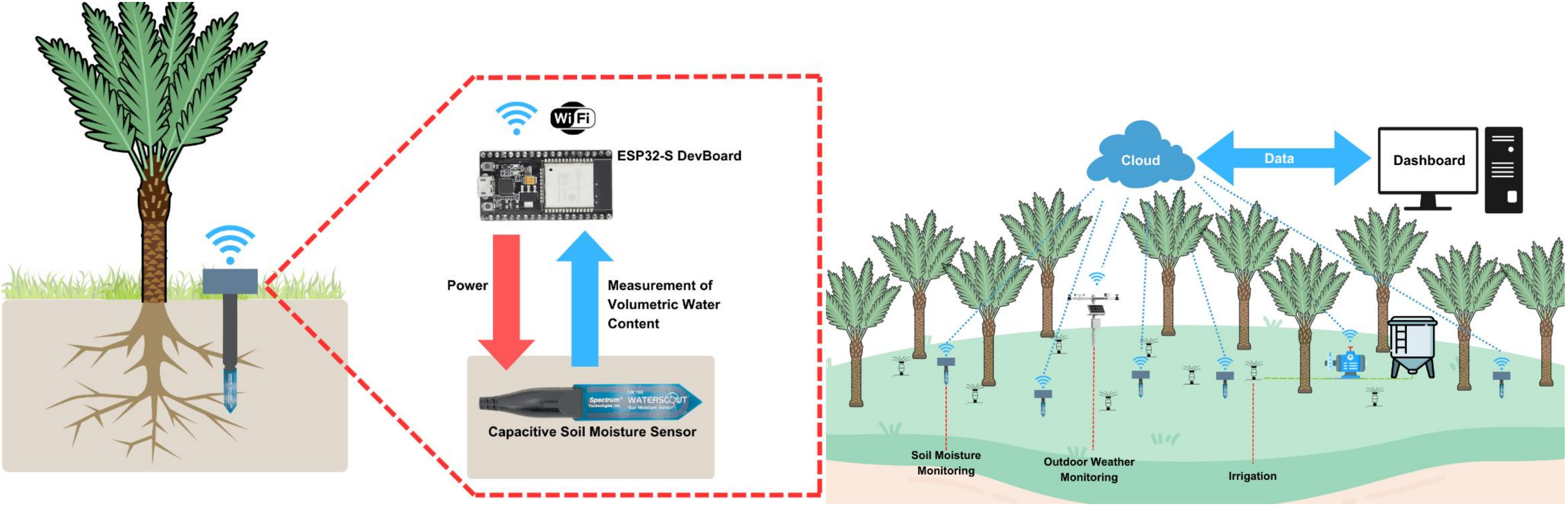
Sample 1
UDST soil
Imported

Sample 2
Farm soil
Local

TDR – In-Situ
Saturation level

Next steps

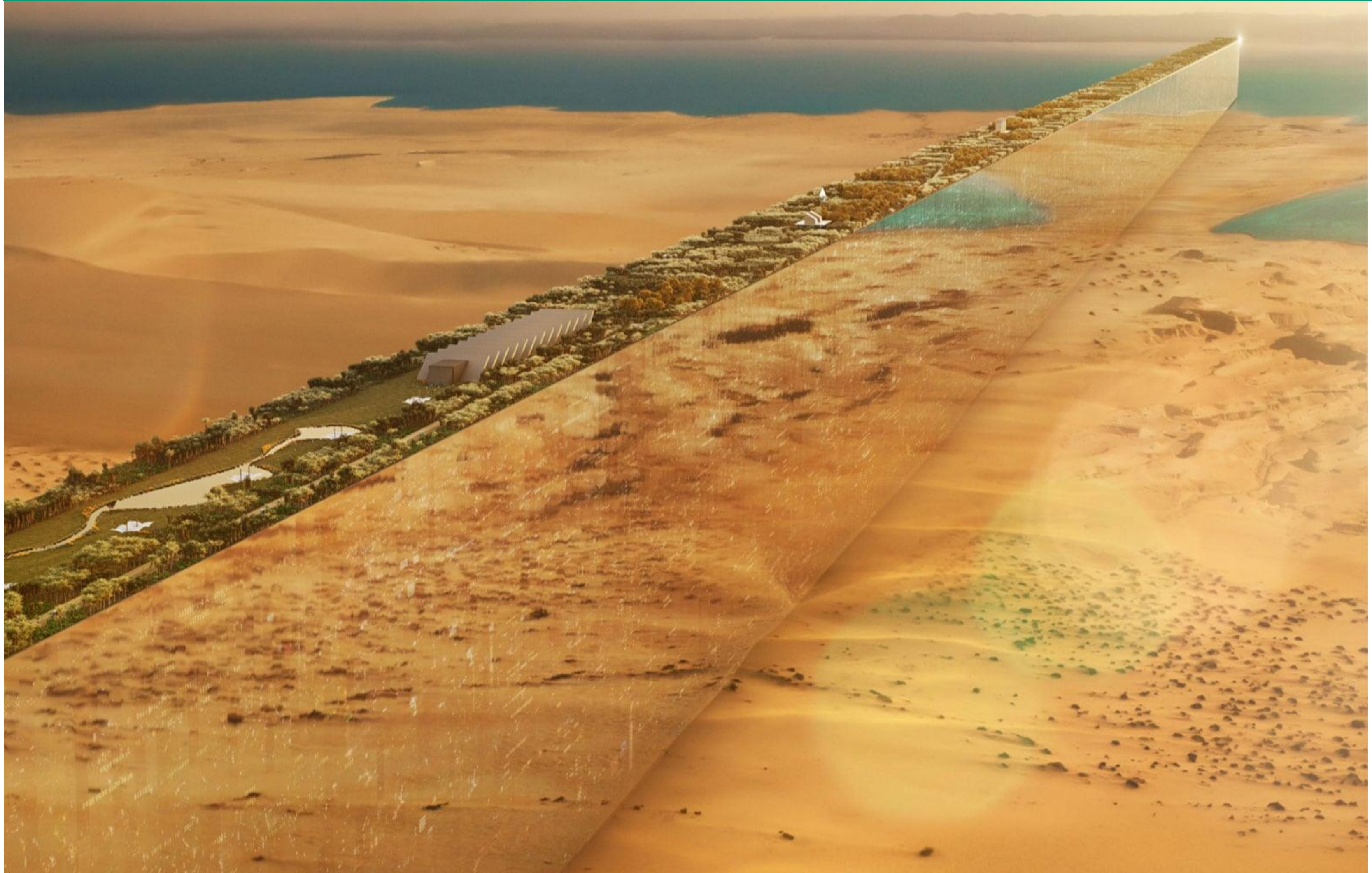
Planned on-site implementation

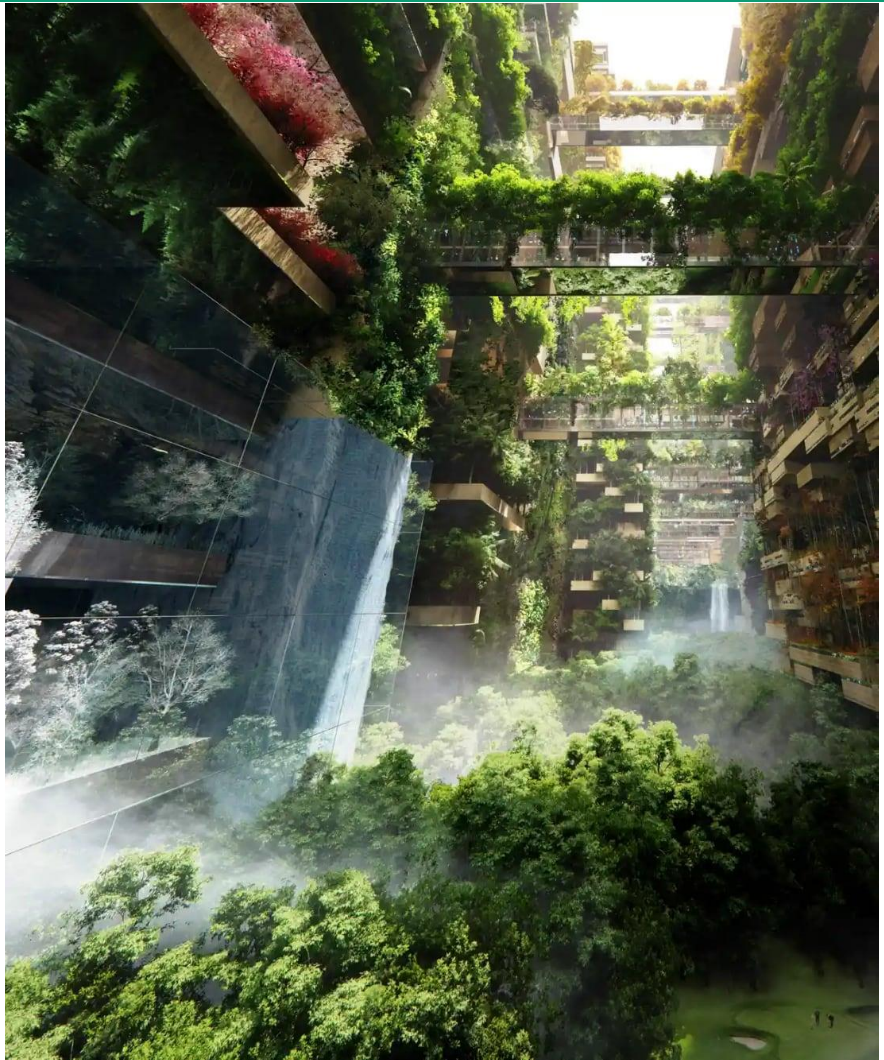


Conclusion

- A Qatar-specific sensor-based automated irrigation system will provide precision irrigation to greenhouse crops and date palm trees.
- Designing, developing, and lab testing tasks of the system have been achieved.
- Calibration of the irrigation sensors is underway for their installation in the real soils or soil substrates for $\vartheta_{\mathrm{FC}} - \vartheta_{\mathrm{WP}}$.
- Irrigation system will turn on ON before ϑ_{WP} and trun OFF at ϑ_{FC}.
- The provision of a Wi-Fi connection is essential to this prototype.

Harsh climate and poor soils will force GCC farmers to adopt greenhouse cultivation – Saudi Arabia Line City will use CEA to grow fruits and vegetables in greenhouses. Sensor-based irrigation system has a great potential to solve water scarcity and management issues.





Credits and Acknowledgements

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Questions, Feedback, and Discussion