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IoT based Sensor System for Estimation of Crop Water Stress Index and Smart Irrigation Scheduling in Maize and Wheat cropping Sequence

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INTRODUCTION

- The current world population of 7.6 billion is expected to reach 8.6 billion in 2030, 9.8 billion in 2050, and 11.2 billion in 2100 (United Nations report, 2017).
- Increasing population growth leads to increase food demands, resulting in an escalation of water scarcity, with an estimated one-third of the global populace projected to confront acute water shortages by 2050 (Amarasinghe and Smakhtin, 2014).
- India has the highest irrigated area (139.90 million hectares) in the world and agricultural sector (irrigation) consumes around 84% of available water resources (Dhawan 2017).
- To meet the growing demand for food and mitigate water scarcity, the application of the Internet of Things (IoT), AI, and Machine Learning for precision agriculture has become paramount.

OBJECTIVES

1. To design an affordable IoT-based sensor system to assess crop water stress index in water-intensive crops like maize and wheat, specifically in the Punjab region of India, for efficient irrigation scheduling
2. To validate the sensor system under cropping system of maize-wheat
3. To schedule the irrigation based on CWSI in wheat and maize crop

Materials and Method

- The study was conducted at Dr. S. D. Khepar Research Farm, Punjab Agricultural University Ludhiana, Punjab
- Soil texture: Sandy soil
- Climate: Semi-arid
- Annual rainfall: 750mm
- Major crop: Wheat, and Maize
- Cropping period: 2019-2021

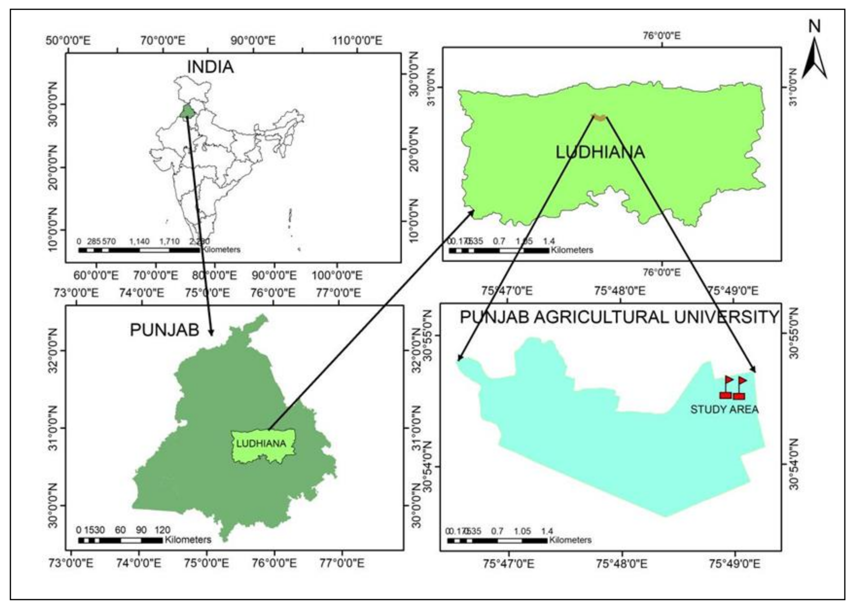

Fig 1. Location of the study area

- Irrigation system: Subsurface Drip Irrigation (SDI)
- Irrigation scheduling: ET_c-based (80%, 90%, and 100% of ET_c) and CWSI based Irrigation
- Irrigation interval: one-day, two-days, and three-days
- Development of IoT-based sensor system and estimation of CWSI threshold values using Machine learning programing in Arduino for irrigation scheduling

Table 1: Soil Physio-chemical properties

Parameters	Depth (cm)			
	0-15	15-30	30-60	60-100
FC (%)	18.37	19.45	22.27	28.80
Wilting point (%)	8.82	9.42	10.27	11.04
Bulk density (g/cm^3)	1.47	1.52	1.58	1.60
pH	7.85	8.01	8.13	8.21
EC (mmhos/cm at 250c)	0.25	0.23	0.23	0.23
OC (%)	2.90	2.90	2.70	2.60
Nitrogen (kg/ha)	161.28	143.36	125.44	107.52
Phosphorus (P) (kg/ha)	203.83	195.77	191.29	186.36
Potassium (K) (kg/ha)	307.32	301.25	287.23	285.21

Table 2: Different input variables

Input data	Details
Meteorological Parameters	All the weather parameters were collected from the weather station installed near research field
Sensors	Fluke 62 Max Plus Handheld IR Thermometer, DHT11, DHT22, and SHT15
Components of IoT-based sensor system	Arduino uno, Solar panel, Power control module, Rechargeable battery, Wi-Fi module
Soil moisture	Frequency Domain Reflectometry (FDR)
Software	Arduino, MATLAB
Cloud	ThingSpeak

Materials and Method

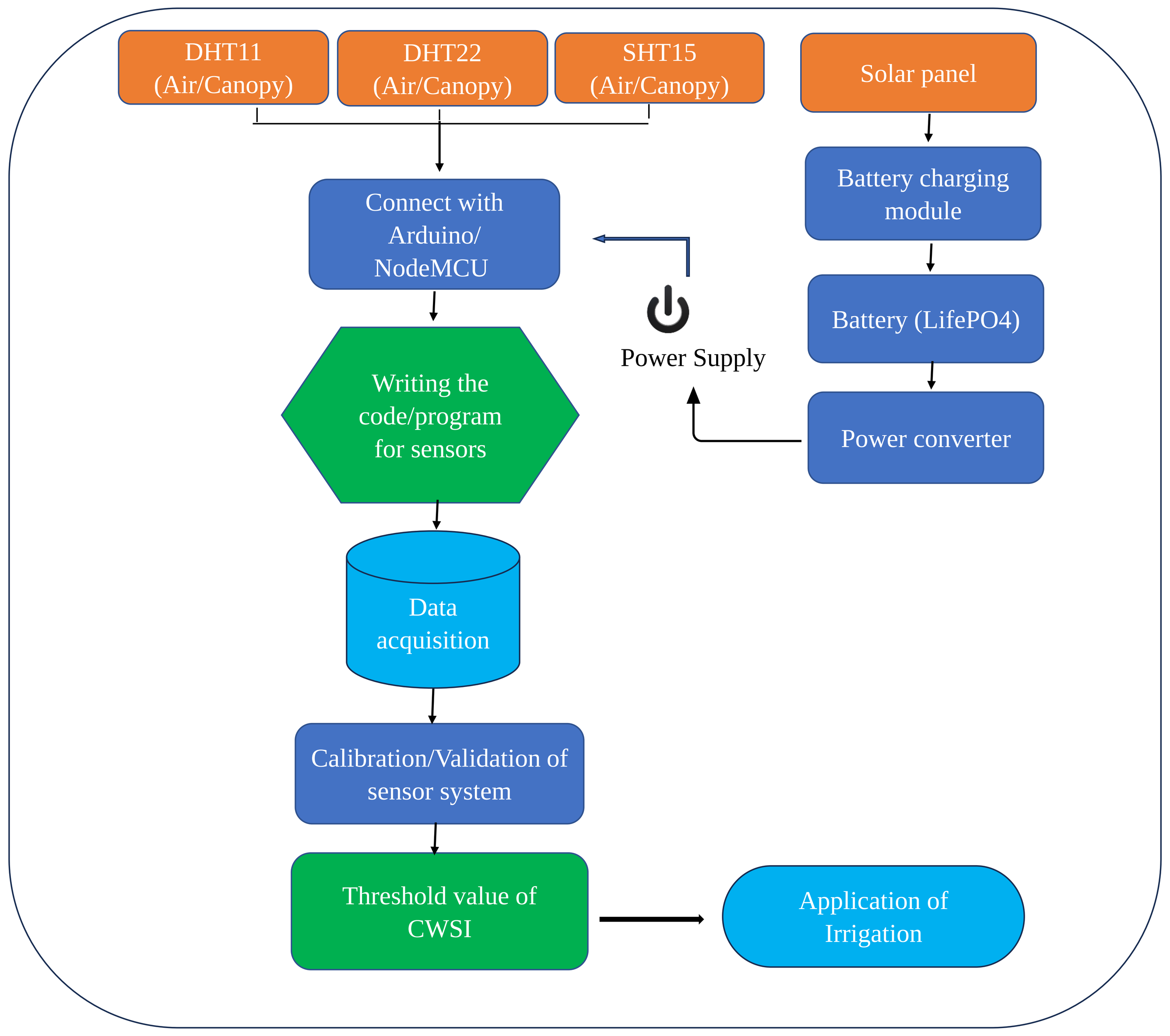

Fig 2. Methodological flowchart for application of sensor-based irrigation

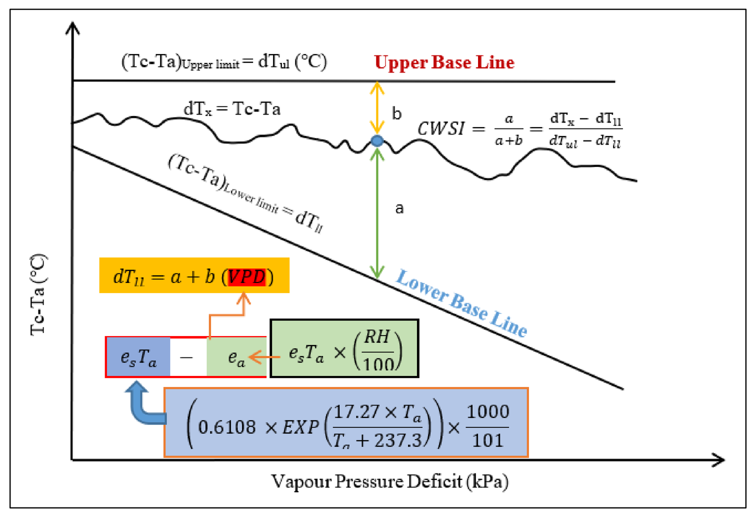

Fig 3. Estimation of CWSI (Idso et al. 1981)

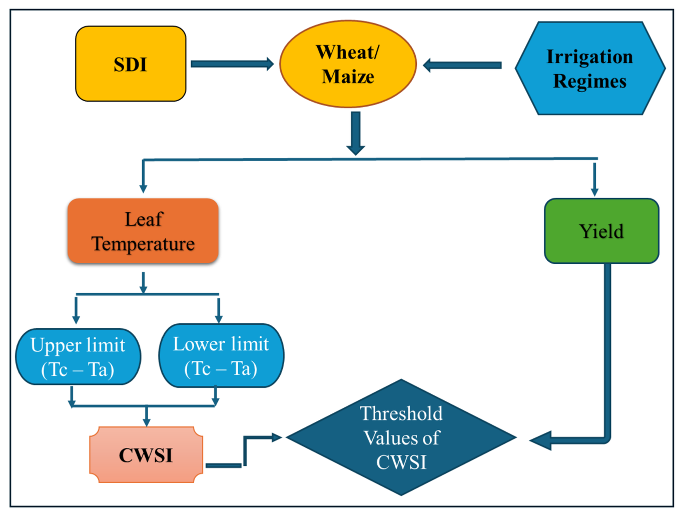

Fig 4. Flowchart for estimation of threshold values of CWSI

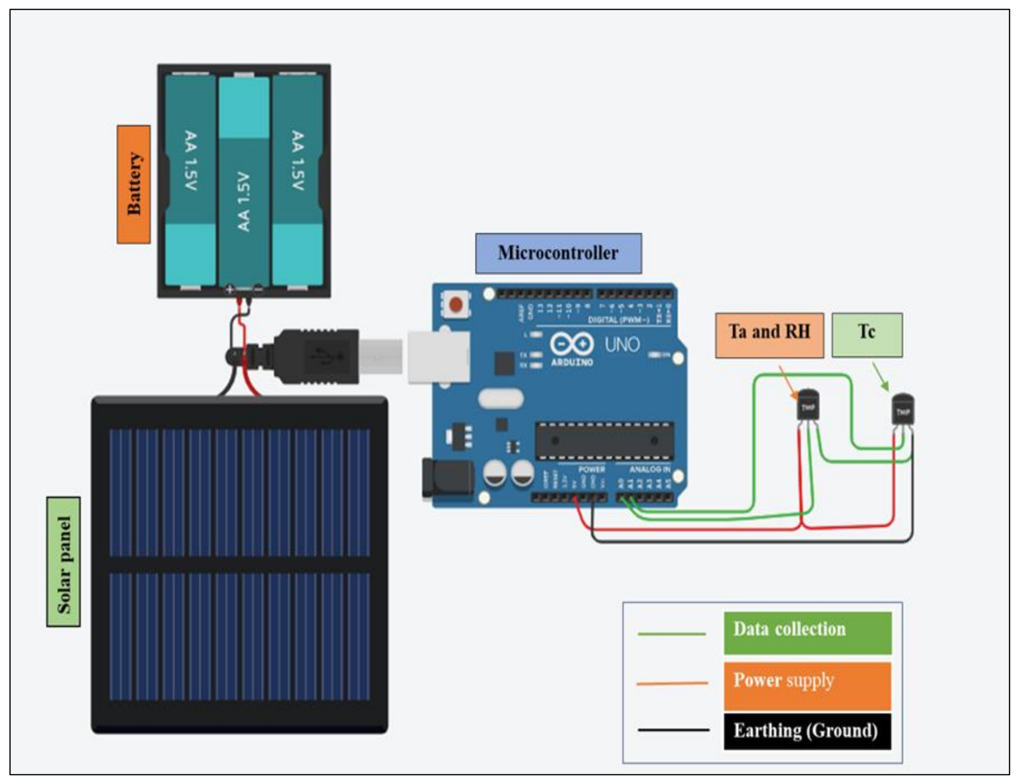

Fig 5. Schematic diagram IoT-based sensor system

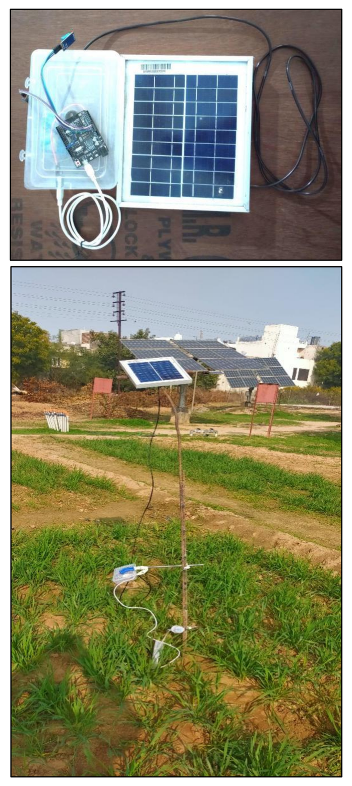

Fig 6. Developed IoT-based sensor system installed in field

Results and Discussion

- The developed sensor system was calibrated and validated in controlled and field conditions using mercury-in-glass and IR thermometers.

Table 3: Calibration and validation of different sensors

Sensor	RSME	MAE (mm/d)	NS	R^2
	Calibration periods			
DHT 11	1.15	0.92	0.71	0.89
DHT 22	0.97	0.83	0.81	0.95
SHT 15	0.94	0.74	0.86	0.97
	Validation periods			
DHT 11	1.44	0.95	0.54	0.91
DHT 22	0.59	0.46	0.84	0.96
SHT 15	0.56	0.43	0.89	0.97

- The upper and lower baseline of canopy air temperature difference (Tc-Ta) for wheat was estimated as **7.5 °C** and **-0.3883 VPD + 3.234**, respectively.
- The upper and lower baseline of canopy air temperature difference (Tc-Ta) for maize was estimated as **6 °C** and **-0.4235 VPD + 5.4252**, respectively.
- Threshold value of CWSI was obtain as 0.29, and 0.365 corresponding to the normalized value of 0.61, and 0.885 for wheat and maize respectively

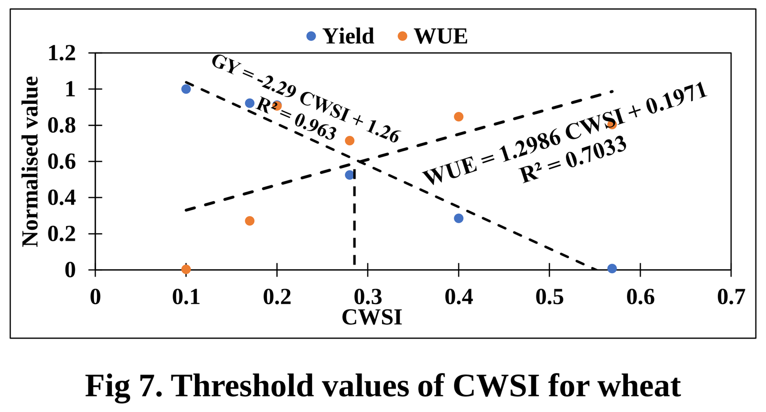

Fig 7. Threshold values of CWSI for wheat

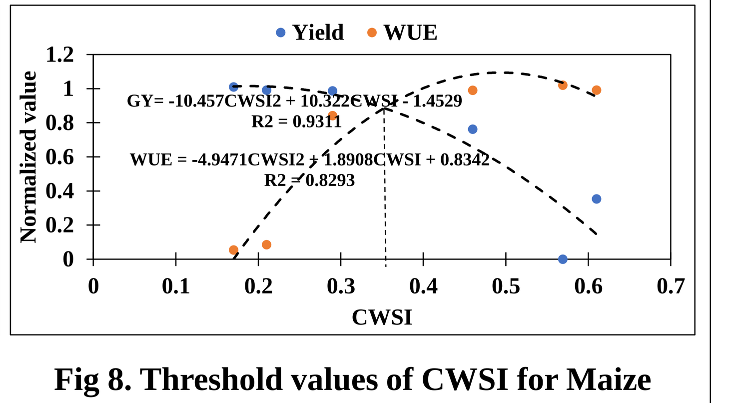

Fig 8. Threshold values of CWSI for Maize

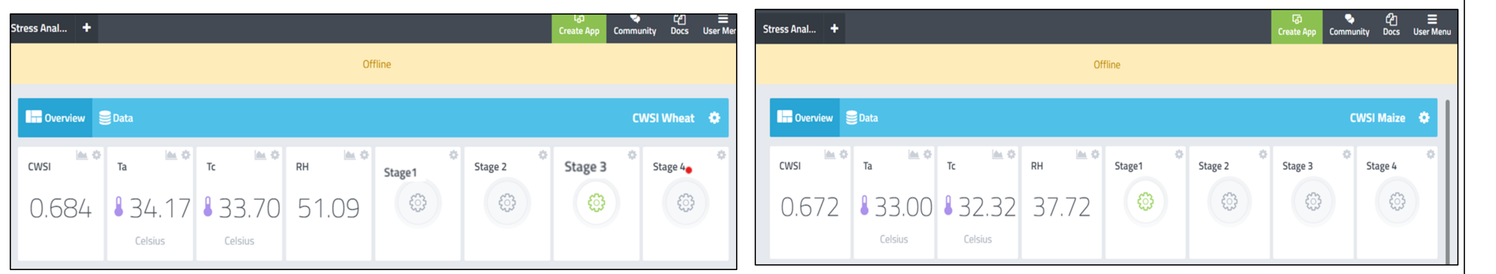

Fig 9. irrigation scheduling based on CWSI for wheat and Maize

- The results showed that sensor-based irrigation were produce 5.02 % and 6.4% higher yield for wheat and maize respectively, as compared to ET_c based irrigation.
- The sensor-based irrigation system saved 15.43% and 19.87% of water in wheat and maize respectively, compared to ET_c-based sub-surface drip irrigation.

Conclusions

- The SHT15-based sensor system performs better with a three-day irrigation interval compared to other temperature sensors.
- Upper and lower baselines for canopy air temperature differences and threshold values of CWSI (0.29, and 0.365 for wheat and maize, respectively) were established for wheat and maize crops in the study area.
- The sensor system indicates the real time water stress in crop based on canopy temperature and indicates for application of irrigation.
- The AI, machine learning, and sensor-based irrigation system enhanced the water use efficiency and yield of wheat and maize

References

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