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DATE: 20 – 22 August 2025

Multi-Temporal Analysis of Taro Crop Water Stress Using High-Resolution Thermal and Multispectral Proximal Sensing for Improved Resilience of Smallholder Farming Systems

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TECHNICAL SESSION 1

Multi-Temporal Analysis of Taro Crop Water Stress Using High-Resolution Thermal and Multispectral Proximal Sensing

SHORT BIO

PhD Environmental Science (*Precision Agriculture - UKZN*)

Rangeland Management, Alien Invasive Plant Control, Solid Waste Management, Water Quality Monitoring and Ecosystem Conservation

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Introduction

- Climate change is a **global environmental threat** that has adverse effects on agricultural crop production.

Challenge:

- **Developing regions** with pre-existing challenges of hunger and food insecurity.
- **Smallholder farming systems** – most vulnerable to the impacts of climate change their reliance on rainfall and lack of resources for climate adaptation and resilience.

- Need for **transformative and climate-smart paradigm shift in agriculture**, that prioritizes **diversification of cropping systems** to incorporate crop species **that build resilience and strengthen the adaptive capacity** of smallholder agricultural landscapes against climate change.

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Introduction

- **Neglected and underutilised crops (NUS):** Taro (*Colocasia esculenta (L)*), also known as Amadumbe.

- Identified as a **future-smart-crop** due to its drought and heat tolerance and its adaptability to adverse environmental conditions.
- **Rich nutritional profile**: carbohydrates, protein, vitamins, and natural sterols.

- **Moisture content** - influences tuber quality, texture and palatability.
- Largely **limited and anecdotal spatial and empirical research** on its **water status and stress responses across the growing season** ~ *hindering its promotion and integration into existing agricultural systems*

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- Studies indicate that under moisture deficit conditions, crops exhibit **several physiological changes** that can serve as reliable **indicators of their water status** (Parkash and Singh 2020, Sobejano-Paz et al. 2020, Wang et al. 2022a).

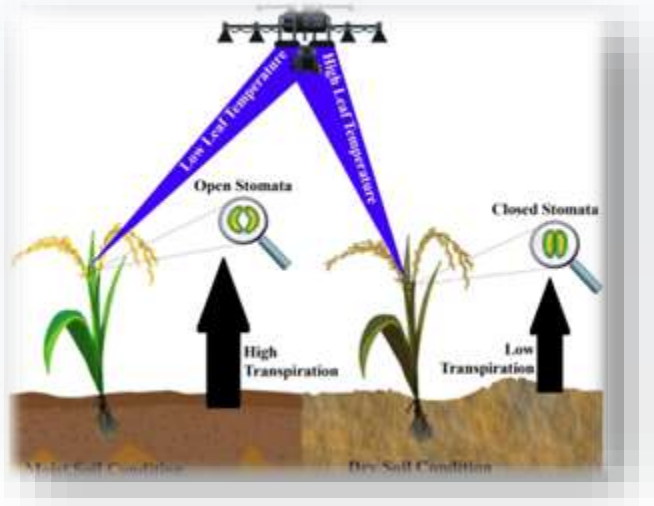
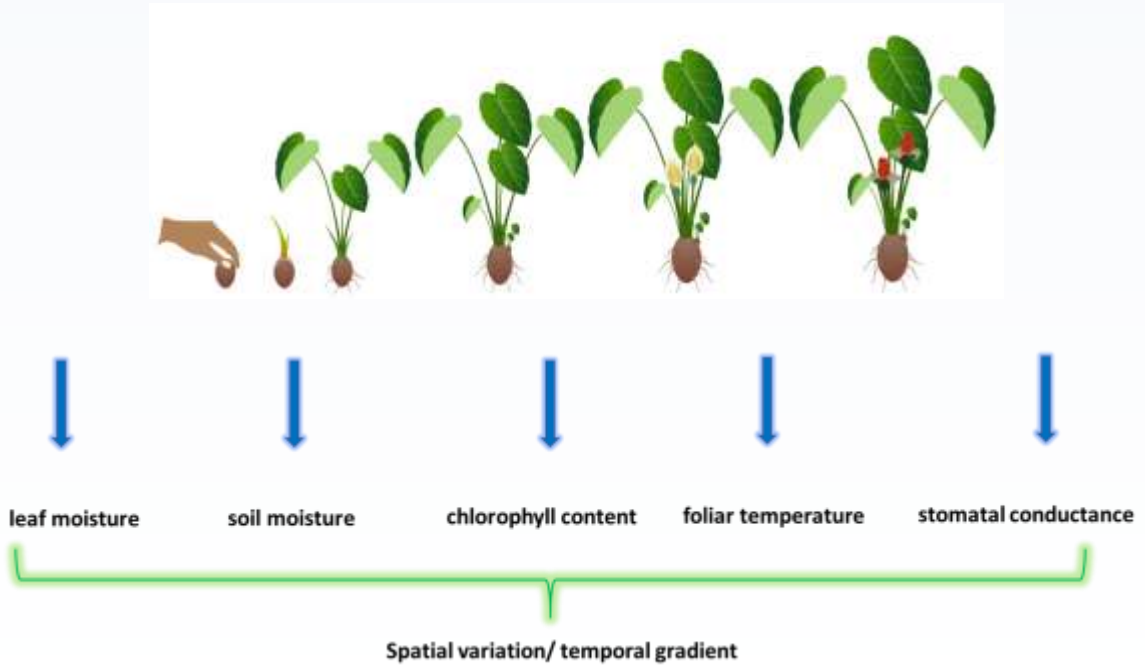


Figure 1: Remote sensing of crop water indicators.



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Introduction

- **Traditional Methods**: time-consuming, laborious, expensive and not feasible for continuous monitoring.
- **Satellite imagery** restricted by their **relatively coarse spatial and temporal resolutions**. ~ *e.g., Sentinel -2 – 10 m*

- **Unmanned Aerial Vehicles (UAVs)** provide high-quality remotely sensed data at **unprecedented spatial, spectral and temporal resolutions** ~ *centimeters, near-real time*
- Mounted with high-resolution **multispectral** and **thermal** cameras.

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Research Aims and Objectives

Research Aim: This study sought to evaluate the utility of UAV multi-modal thermal and multispectral remote sensing in assessing and monitoring the crop water status of neglected and underutilized taro crops within smallholder farming systems

Specifically, the study sought to

1) Predict **stomatal conductance and leaf temperature** using UAV multi-modal thermal and multispectral data at the **emergence, vegetative and maturity growth stages** and

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Materials and Methods

Swayimane, KwaZulu-Natal, South Africa

- **Organic Farming Systems**
- **Vulnerable to Climate Change Impacts**

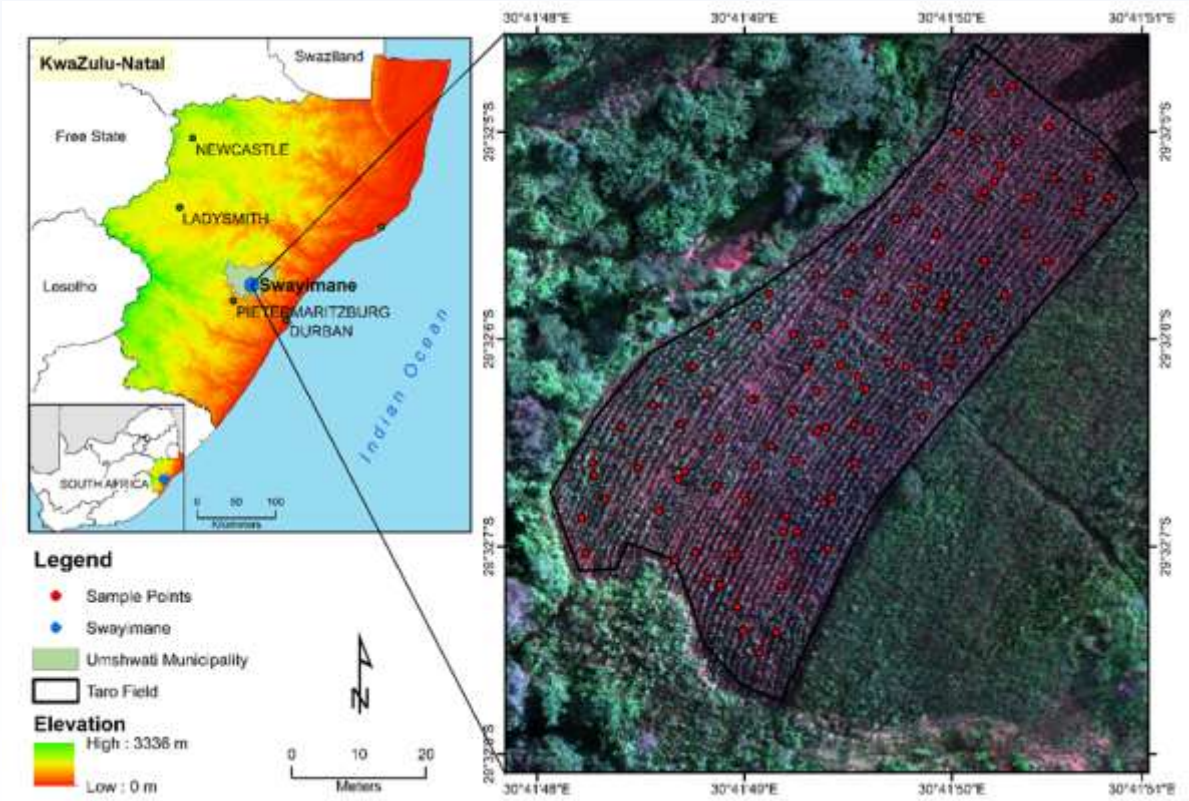

Figure 2: (Left) Location of the study area in Swayimane, South Africa (29° 52’ S, 30° 69’ E) and (Top) taro field during the vegetative growth stage

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Materials and Methods

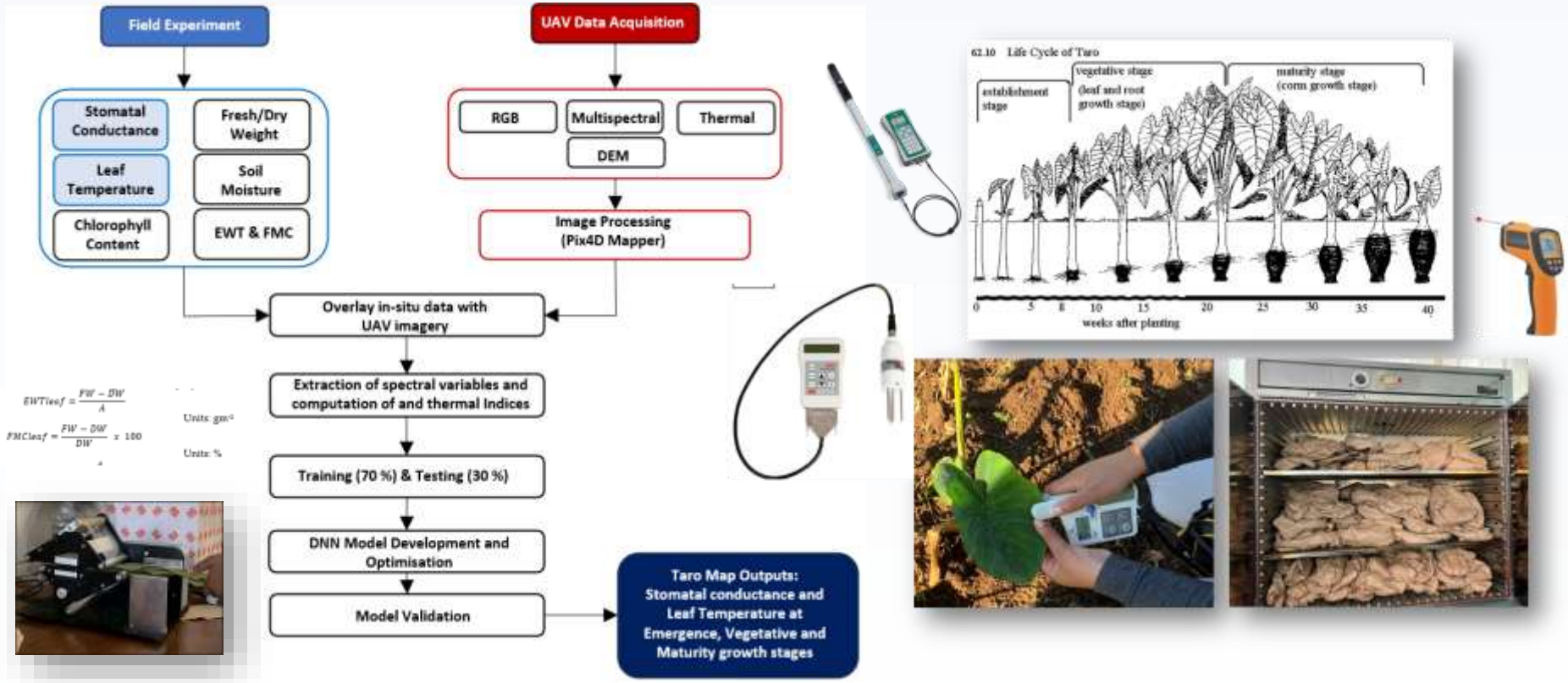

Figure 3: Flow chart of methodology implemented in this study.

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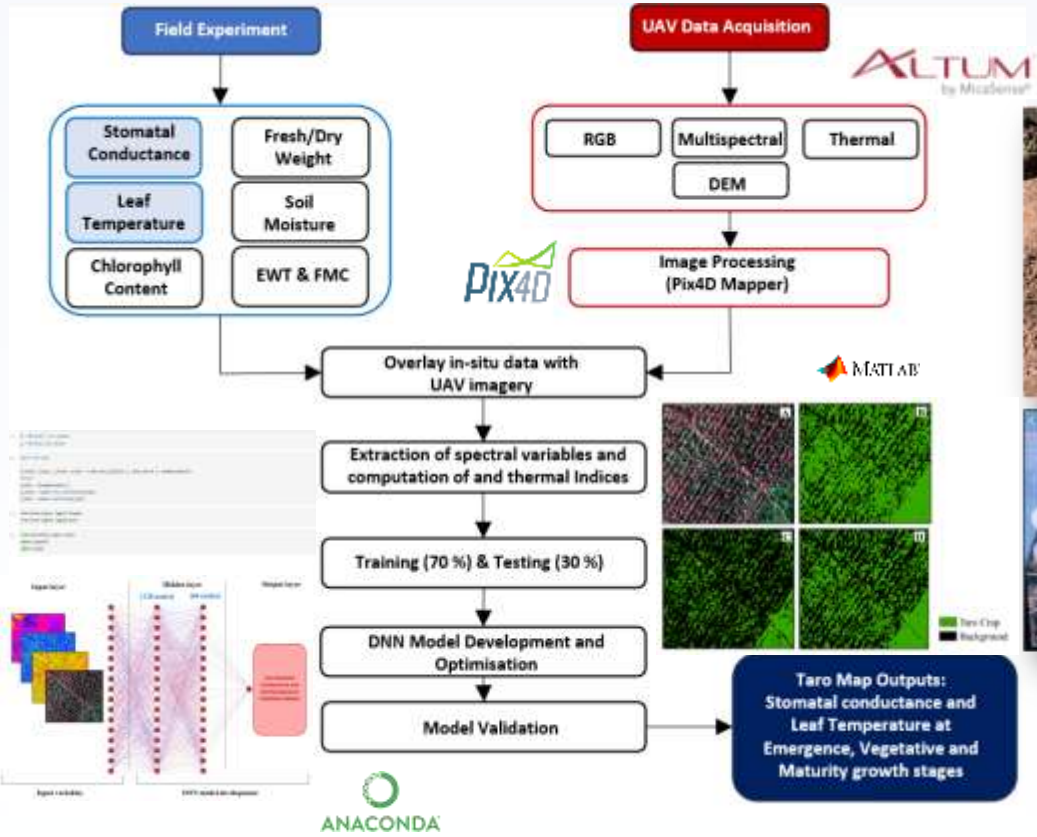
Materials and Methods



DJI Matrice 300

Spatial Resolution: 9.6 cm

Spectral Range: Blue, green, red, red-edge, NIR and thermal

Figure 3: Flow chart of methodology implemented in this study.

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Key Research Findings

- Significant presence of **non-target elements such as soil and weeds** in taro crop images **introduce noise and can obscure the features of interest**, hindering the model's ability to accurately learn and predict.

Figure 6. (Left) Taro field without weeds (Right) and Taro field with weeds.

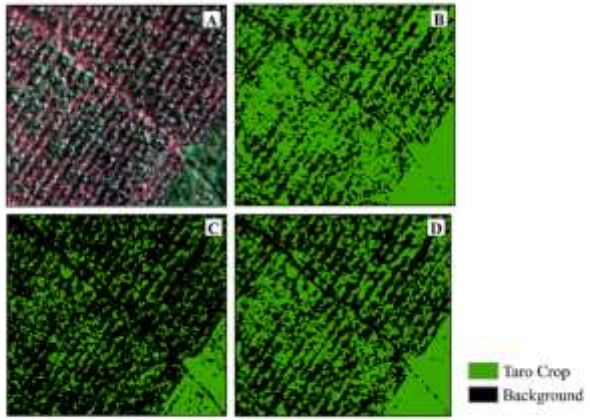

Figure 3.2 Taro crop canopy extraction: a) raw UAV image, b) ExG, c) ExR and d) ExGR canopy extraction.

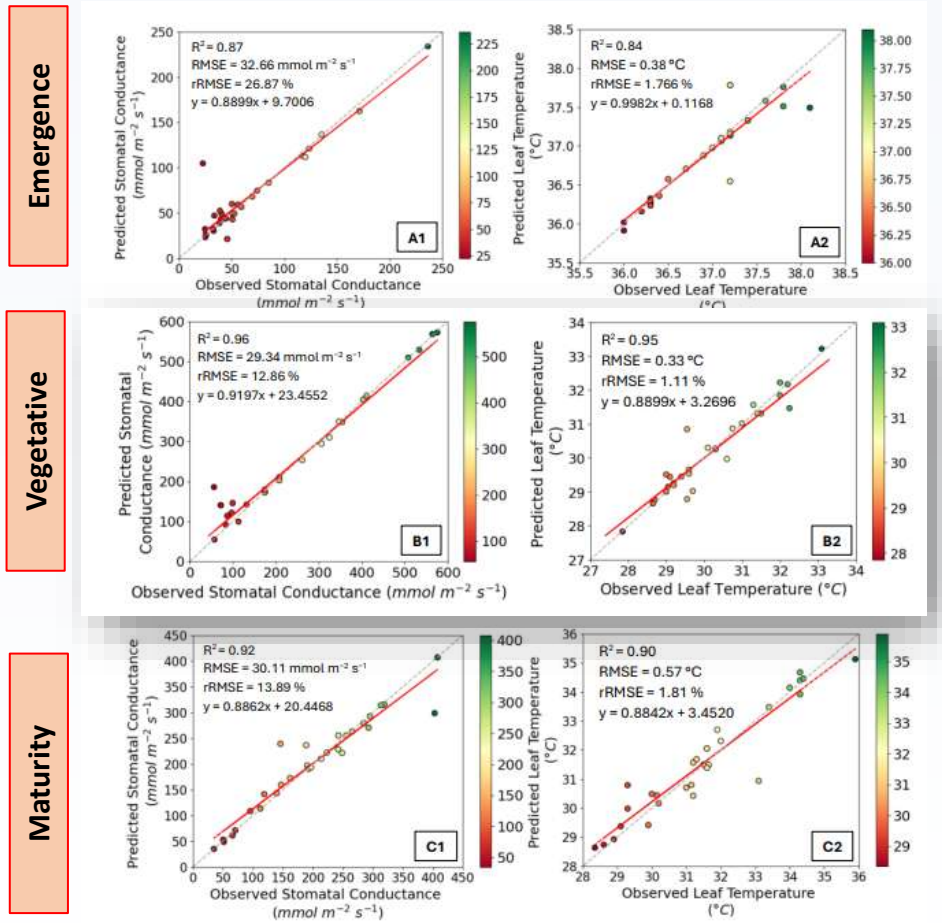

Figure 5. Relationship between observed and predicted a) stomatal conductance and b) leaf temperature during the 1) emergence, 2) vegetative and 3) maturity growth stages.

- The **vegetative growth stage** produced the most optimal estimation models.
- Explained by **higher above-ground biomass accumulation** and **reduced soil interference**.

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Key Research Findings

- **Stomatal conductance** values **below 50 mmol m^{-2} s^{-1}**, indicating potential stress conditions.
- Taro crops with **leaf temperatures below 10 °C and exceeding 35 °C** were identified as potentially stressed crops.

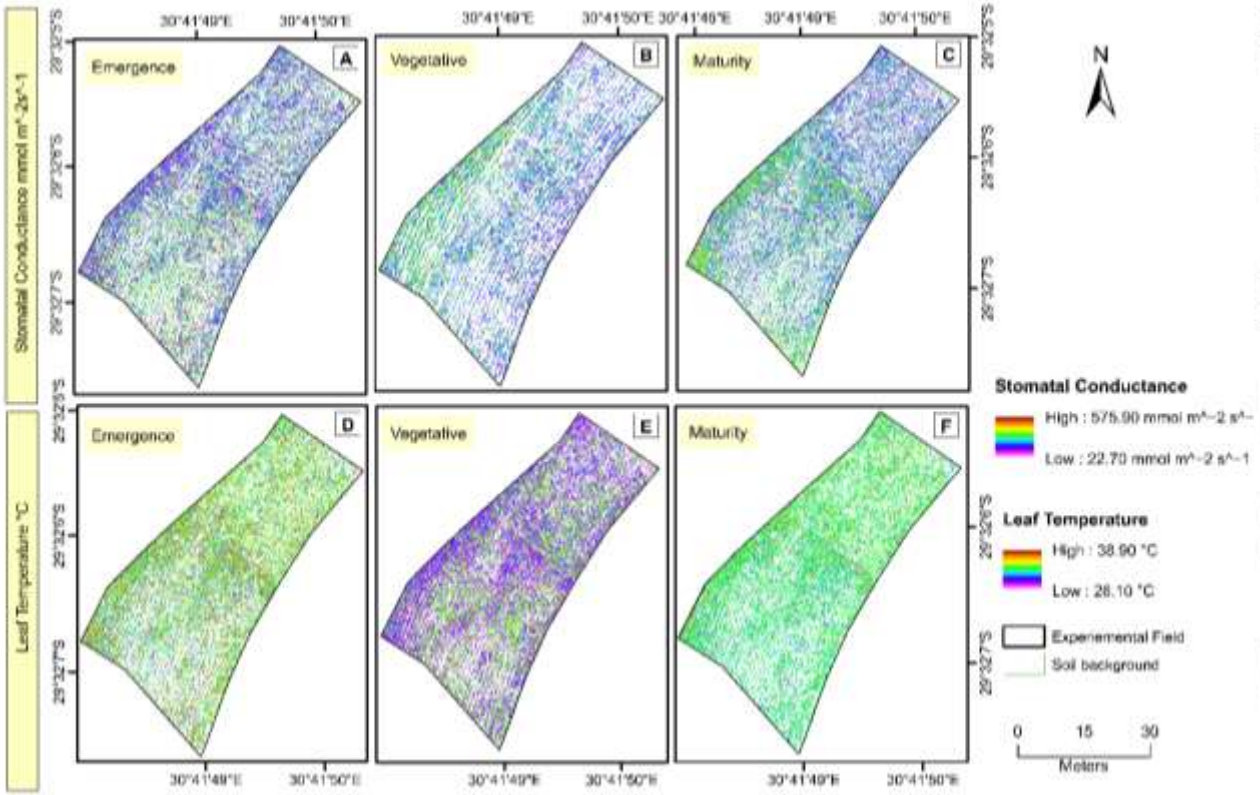

Figure 6. The spatial and temporal distribution of stomatal conductance (a-c) and leaf temperature (d-f) across taro growth stages: emergence (a, d), vegetative (b, e), and maturity (c, f).

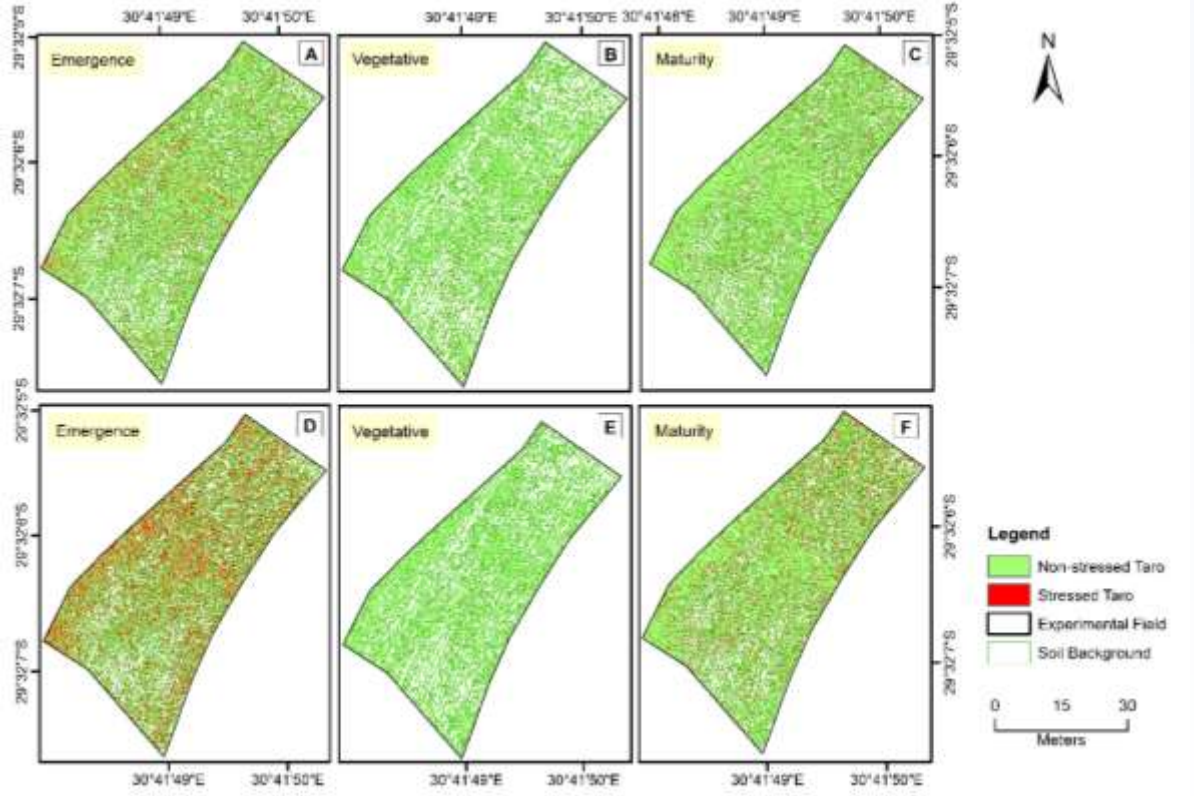

Figure 6. Spatial distribution of potential water-stressed taro crops based on the stomatal conductance (a-c) and leaf temperature (d-f) thresholds across taro growth stages: emergence (a, d), vegetative (b, e), and maturity (c, f).

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Space for Transformation: Public Value

- **Community-Based Focus** – Research aimed at improving smallholder farming practices and ensuring local and regional food security.
- **Employment Value-Add** – Locals employed as field labours
- **Improved crop management strategies** – areas requiring supplemental irrigation
- **Farmer-Centric Agricultural Dashboard** – Prospective Research Initiative
- **Youth Inspiring** – local enthusiasm and interest

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Thank You