# Module 3: Monitoring Land Surface Temperature through the hybrid use of UAV and remote sensing imagery.

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# Module content

- With a case study, you will learn about an experimental approach to monitor land surface temperature changes through the joint use of remote sensing and drone imagery.

- The research was carried out in Tanzania as part of the monitoring and evaluation activities of Justdiggit projects (see - Module 2). It is based on the data collected by MetaMeta in 2018 and elaborated by Lorenzo Villani (MSc student @ UNIFI).

- Tree cover helps buffering extreme temperatures. It contributes lowering maximum temperatures, by reducing solar radiation during daytime. It also helps increasing minimum temperatures, because of reduced emission of infrared radiation at night (Boffa, 1999).

# Research Questions

- Is there a clear correlation between plant cover and Land Surface Temperature?

- What is the threshold of Tree Cover that has a significant effect on microclimate?

# Introduction

- A remote sensing approach is used with a focus on **Land Surface Temperature** (LST), the temperature of the Earth's surface. The temperature of the soil top-layer is more likely the variable to which LST can be approximated better, but LST is also a predictor of many variables retrieved through remote sensing (Sobrino *et al*., 2016), such as air temperature (Cristóbal *et al*., 2008) and soil moisture (Petropoulus *et al.*, 2015), as well as indexes that measure crop stress.

- The temperature registered by the satellite sensor and used to compute LST includes the surface temperature of all features in the scene: in our case plants and soil are predominant . By coupling LST (from Landsat) with plant cover (from UAV), we get an impression on how increased vegetation influences the overall surface temperature and at what levels this takes place.

# The project

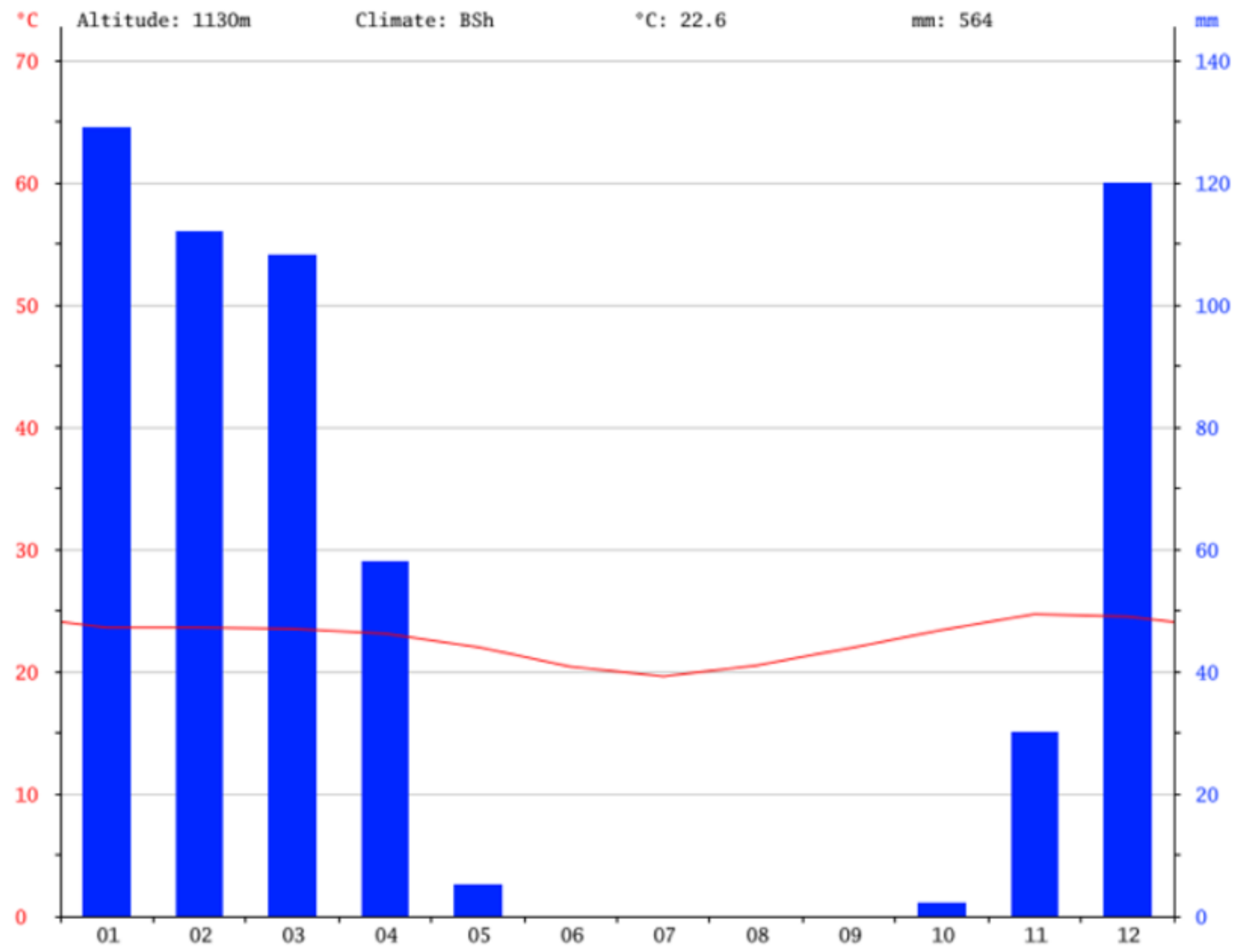
- Name: «Regreening Dodoma / Kisiki Hai»
- Partners: Justdiggit (Netherlands), LEAD Foundation (Tanzania) and MetaMeta (Netherlands)
- Objective: scale-up FMNR and water harvesting techniques to restore degraded land in 300 communities of Dodoma region.
- Methodology: Training of trainers, 1296 facilitators trained
- Beneficiaries: almost 200,000 households
- Aim: ± 200,000 hectares restored
- Period of implementation: December 2017 - 2021

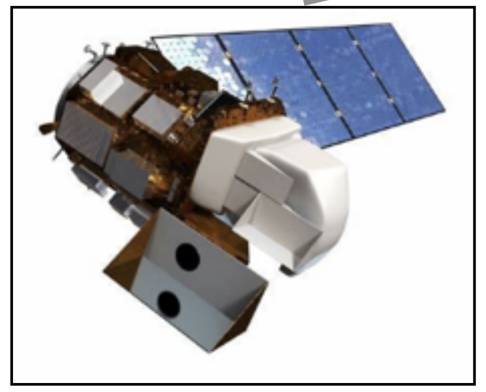
# Methods

- Analysis of RGB UAV maps to calculate plant cover through Supervised Classification (ArcGIS) and manual digitalisation (QGIS).
- Calculation of LST with Practical Single Channel (PSC) algorithm applied to Landsat 8 scenes.
- Resample plant cover raster to match LST resolution and position.
  - Output: two grids, perfectly matching and both with a resolution of 30 m.
- Extraction of the plant cover percentage and LST per pixel
- Statistical analysis to assess the correlation between plant cover Percentage and LST.

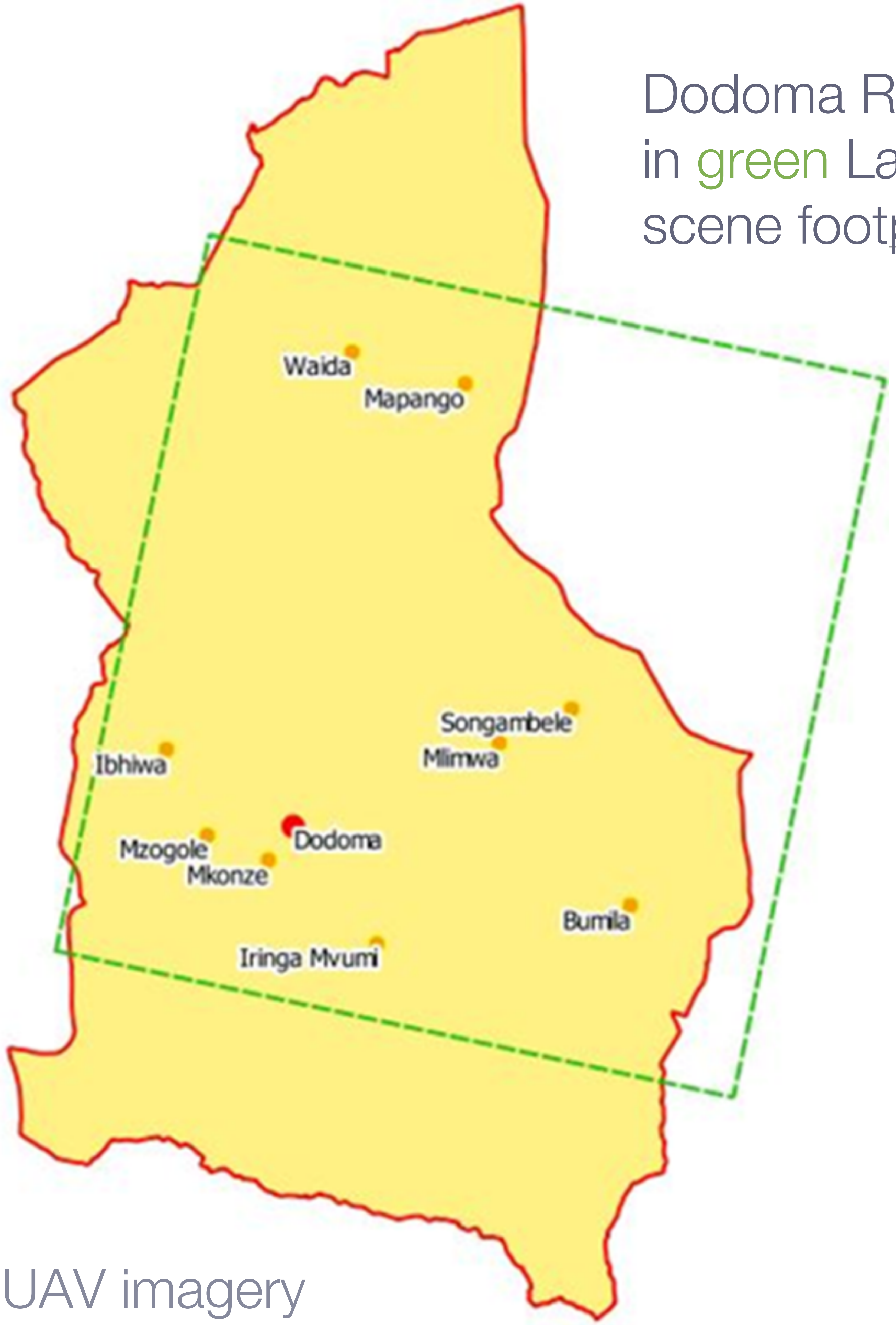
# Study Area

Central Tanzania
Semi-Arid climate with one pronounced rainy season



Satellite and UAV imagery
from 2018 dry season




Dodoma Region -
in green Landsat
scene footprint

# Use of Practical Single Channel (PSC) algorithm

Why PSC:

- Recent (2018)
- Landsat 8 (high resolution)
- Single Channel Algorithm: it uses one band in the Thermal Infrared range (10-12 μm).
- Atmospheric Water Vapour (AWV) in the study area < 3 g/cm2
- Easy to apply

PSC characteristics:

- Inputs: radiance, Land Surface Emissivity and AWV.
- Radiance from band 10 of Landsat 8.
- Emissivity calculated through an NDVI-threshold method
- AWV obtained from MODIS product

# Materials and Methods:
# the Practical Single Channel algorithm

First, the blackbody radiance with a temperature of Ts is calculated with the formula:

$$B(T_s) = a_0 + a_1 w + (a_2 + a_3 w + a_4 w^2)\frac{1}{\varepsilon} + (a_5 + a_6 w + a_7 w^2)\frac{1}{\varepsilon} L_{sen}$$

Then, LST is retrieved inverting the Planck's function:

$$T_s = \frac{c_2/\lambda}{\ln\left(\frac{c_1}{\lambda^5 \cdot B(T_s)} + 1\right)}$$

Lsen = at-sensor radiance ($W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$)
ε = emissivity
λ = effective wavelength (μm)
w = AWV content ($g/cm^2$)
$c_1$ = 1.19104 × 108 $W \cdot \mu m^4 \cdot m^{-2} \cdot sr^{-1}$
$c_2$ = 1.43877 × 104 μm·K
$a_n$ = coefficients

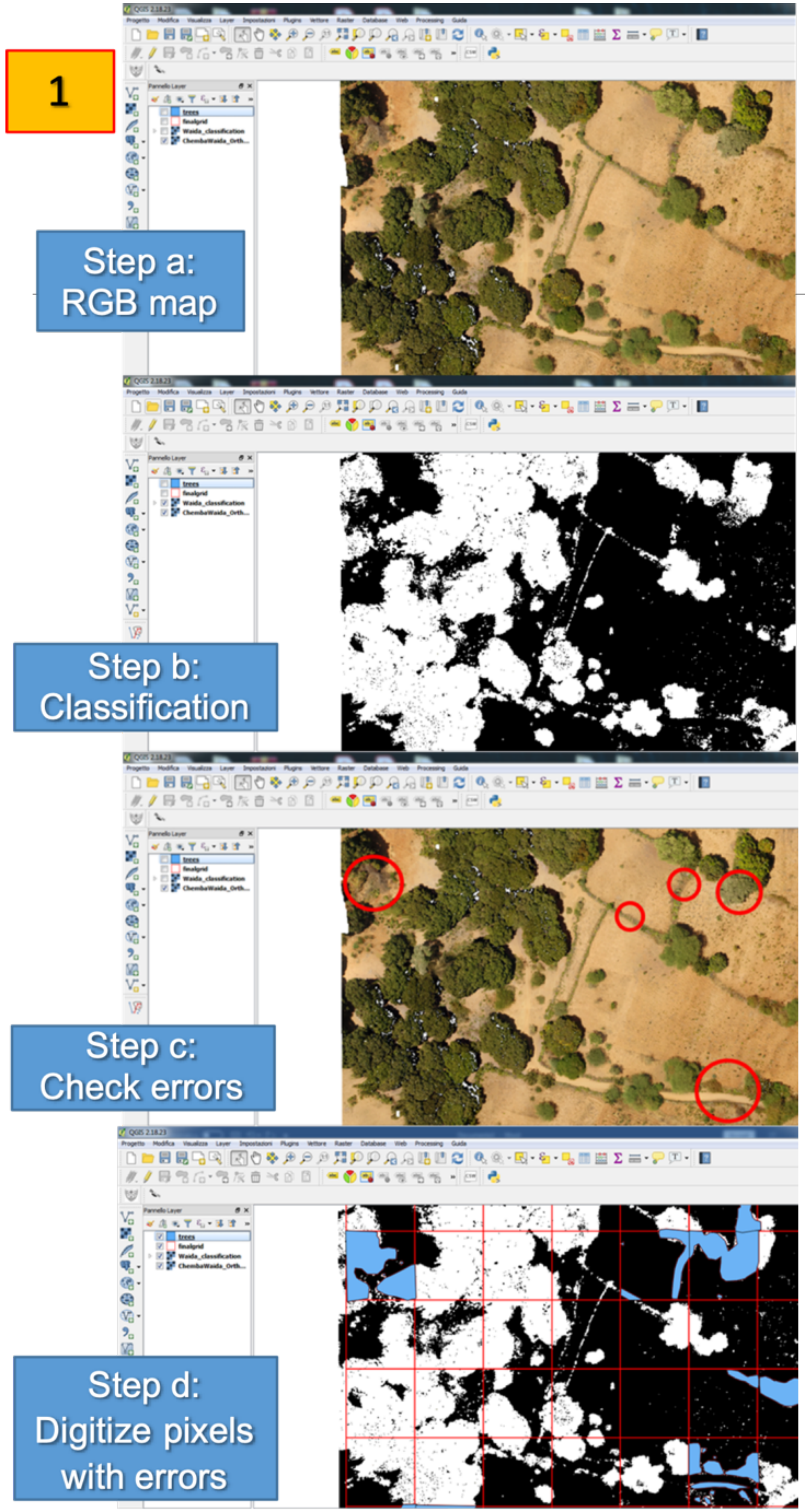
Reference: Wang M., Zhang Z., Hu T., and Liu X., 2018. "A Practical Single-Channel Algorithm for Land Surface Temperature Retrieval: Application to Landsat Series Data." *Journal of Geophysical Research: Atmospheres*: 124, 299–316. https://doi. org/10.1029/2018JD029330

# Drone imagery

- DJI Phantom 4 standard.
- Mission planner software: DroneDeploy.
- Map engine software: DroneDeploy.

Maps characteristics:

- 9 maps
- Average size: 50-70 ha
- Agricultural landscapes





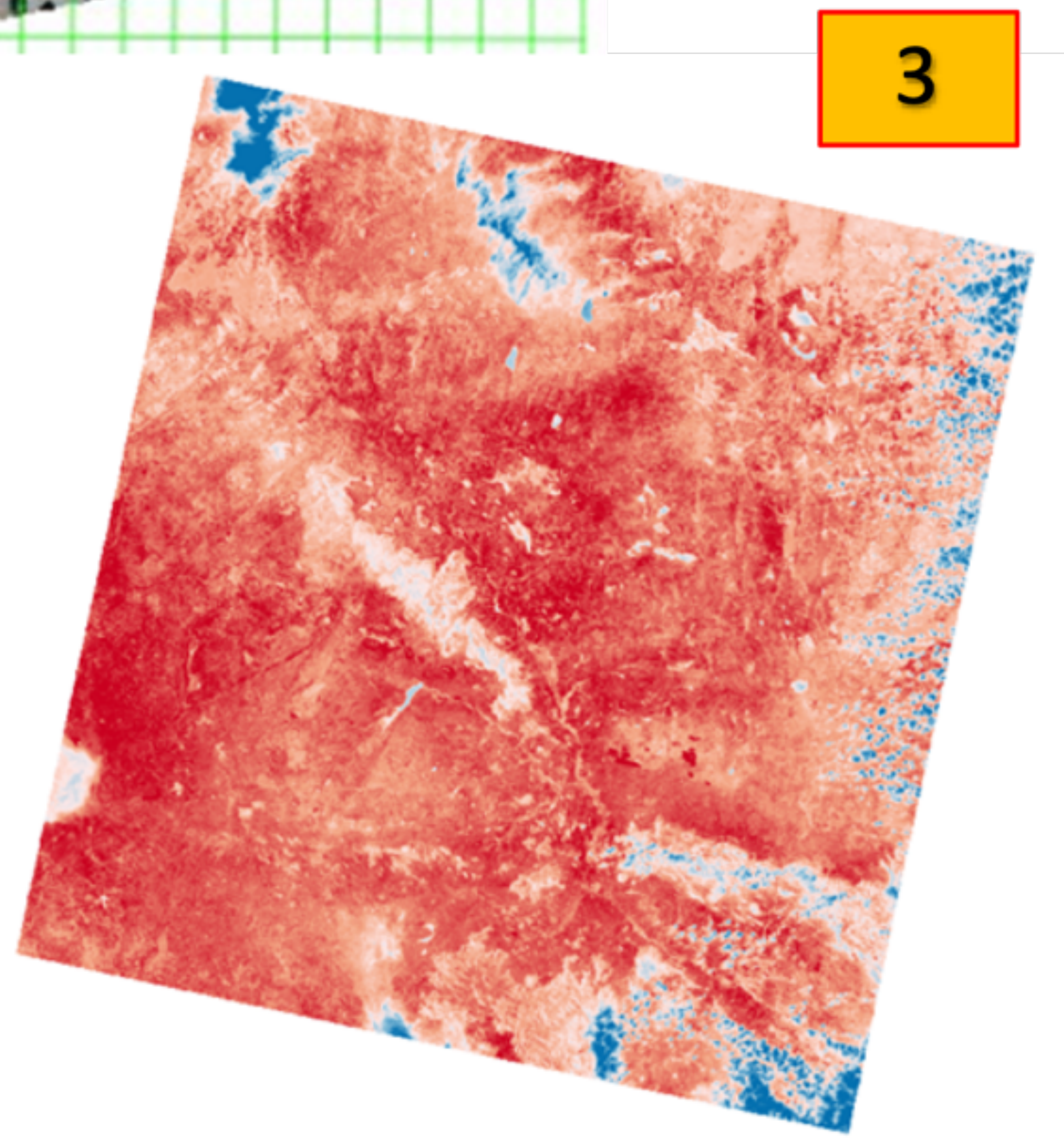



**Figure 1**: UAV RGB elaboration steps (a-d)

**Figure 2:** RGB map with overplayed Landsat grid (in red the selected pixels for statistical analysis)

**Figure 3:** LST map

# Methods: Data Analysis

Data were analysed in two ways:

1. A Pixel Based Analysis (PBA), considering every pixel;
2. A Class BasedAnalysis (CBA), classifying pixels according to the TreeCover Percentage (see Table).

Table: Classification criteria

| 10 | 20 | 30 | 40 | 50 | 60 | 100 |
|---|---|---|---|---|---|---|
| 0-9% | 10-19% | 20-29% | 30-39% | 40-49% | 50-59% | 60-100% |

The statistical analysis was performed through:

1. Linear Regression
2. Analysis of Variance

# Results: Overview

| | Tree cover % | N° of classes | Class 10 (%) | Class 20 (%) | Class 30 (%) | Class 40 (%) | Class 50 (%) | Class 60 (%) | Class 100 (%) |
|---|---|---|---|---|---|---|---|---|---|
| Bumila | 7,2 | 4 | 75,6 | 20 | 4 | 0,4 | | | |
| Ibhiwa | 4,7 | 5 | 83,6 | 12,3 | 3,3 | 0,3 | 0,3 | | |
| Iringa Mvumi | 3,0 | 6 | 90,6 | 5,9 | 2,1 | 1 | 0,3 | 0,1 | |
| Mapango | 0,9 | 2 | 98,2 | 1,8 | | | | | |
| Mkonze | 4,9 | 3 | 89,1 | 10 | 0,9 | | | | |
| Mlimwa | 5,0 | 6 | 81,7 | 12,3 | 3,7 | 1,4 | 0,6 | 0,3 | |
| Mzogole | 3,6 | 3 | 94,3 | 5,3 | 0,4 | | | | |
| Songambele | 0,8 | 3 | 98,1 | 1,6 | 0,3 | | | | |
| Waida | 18,2 | 7 | 48,5 | 22,6 | 15,3 | 6,8 | 4,4 | 2,4 | 7,7 |
| **TOT** | **5,1** | | **85,0** | **9,5** | **3,3** | **1,1** | **0,7** | **0,3** | **0,9** |

For the CBA maps with 3 classes or less, and/or maps with an occurrence of class 30 < 1% were excluded from the analysis.

Classes <= 3
AND/OR
Class 30 < 1%

# Results

1. **PBA**: Poor results in terms of R2.
2. **CBA:** Good results in terms of R2 and regression line's coefficient for the maps with **>7% TreeCover Percentage** in the **late dry season.**

| Coeff / $R^2$ | 03-04-2018 | 05-05-2018 | 21-05-2018 | 06-06-2018 | 24-07-2018 | 09-08-2018 | 10-09-2018 | 26-09-2018 | 12-10-2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Bumila** | | | | 0,0431<br>0,9146 | | **-0,1898<br>0,915** | **-0,2565<br>0,9857** | | |
| **Ibhiwa** | | | | 0,0591<br>0,8901 | 0,0824<br>0,8132 | 0,0727<br>0,5914 | 0,068<br>0,2932 | 0,0711<br>0,196 | 0,0259<br>0,1505 |
| **Iringa Mvumi** | -0,1187<br>0,5755 | | | 0,0633<br>0,1842 | | -0,0848<br>0,1921 | -0,0173<br>0,017 | 0,0215<br>0,0482 | -0,0663<br>0,5951 |
| **Mlimwa** | | | -0,0222<br>0,0351 | -0,0883<br>0,1124 | | -0,074<br>0,1311 | -0,1322<br>0,421 | -0,2094<br>0,6781 | |
| **Waida** | | | | -0,0434<br>0,0798 | | **-0,2149<br>0,9585** | **-0,2053<br>0,9554** | **-0,2482<br>0,9369** | **-0,3027<br>0,9395** |

ANOVA was performed for the maps of Waida and Bumila ($p<0,05$).

# Results - difference in LST (Δt)

| Bumila | |
|---|---|
| Significant scenes | 09-08-2018<br>10-09-2018 |
| Average Δt<br>(T class 10 – T class 30) | 0.45 °C |
| Average Δt<br>(between adjacent classes) | 0.23 °C |

| Waida | |
|---|---|
| Significant scenes | 09-08-2018<br>10-09-2018<br>26-09-2018<br>12-10-2018 |
| Average Δt<br>(T class 10 – T class 60) | 1.33 °C |
| Average Δt<br>(between adjacent classes) | 0.27 °C |

- The average decrease in temperature between the class with less and the one with more trees was found to be 0.45 °C in Bumila and 1.33 °C in Waida.
- The average decrease in temperature with an increase in 10% Tree Cover Percentage is 0.23 °C for Bumila and 0.27 °C for Waida.

# Answers to research questions

- Tree Cover Percentage negatively correlated with Land Surface Temperature in areas with Tree Cover Percentage higher than 7% in the late dry season.
- The average decrease in temperature is 1.33°C for Waida and of 0.45°C for Bumila.
- The average decrease in temperature between adjacent plant cover classes is 0.23°C and 0.27°C for Bumila and Waida, respectively.
- Average Tree Cover Percentage is 5.1% (across all mapped sites).
- Threshold of 10% Tree Cover Percentage (roughly 50 trees per hectare) to have an ameliorated microclimate.

# Conclusions

- Tree Cover Percentage at regional level is very low;
- The inclusion of trees showed positive effects.
- Methods used were appropriate, but can be improved
  - Add multispectral camera to the drone for better land cover classification.
  - Synchronise image acquisition.
  - Geo-script the process in Google Earth Engine
  - Expand the research to investigate the relation between WH structures and LST.
- Evidence to support Microclimate management to tackle climate change at local level

Thank you!

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