Association of Irrigation Acceleration Platform (AIAP)

WATER PRODUCTIVITY IN PRACTICE KNOWLEDGE & ACTION (WATERPIP-KAN)

REPORT NO. 5

Mapping Major Irrigated Crops using Sentinell-II and Drones mounted with IR Camera in Upper Ewaso Ng'iro Basin, Kenya

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ABOUT THIS REPORT

Synopsis

The Association of Irrigation Acceleration Platform (AIAP) based in Kenya, is working collaboratively under a contract with the Stichting IHE Delft Institute for Water Education (IHE-Delft), as part of the DUPC3 Programme. This implements the Water Productivity in Practice Knowledge & Action Network (WaterPIP-KAN) project. The project duration is 4 years, from 27th November 2023 to 31st December 2027. The WaterPIP-KAN project decisively targets and is inclusive of remote and marginalized communities who constitute the grassroots beneficiaries and implementation partners of the project in Kenya. AIAP's role is to facilitate project out-scaling and knowledge transfer in Kenya. But AIAP has highly qualified staff at PhD levels who are experts in Remote Sensing and GIS, including conducting hydrological, water balance and crop modelling in a GIS interface.

This is the 5th Progress Report submitted by AIAP to IHE-Delft, covering the period January – June 2025. This particular report is entitled: "*Mapping Major Irrigated Crops using Sentinell-II and Drones mounted with IR Camera in Upper Ewaso Ng'iro Basin, Kenya"***.** It follows on the heels of four earlier reports, i.e.: (i) Report 1: Methodology for Identifying Marginalized Groups for WATERPIP-KAN Project Engagement; Report 2: "Identifying sites for community engagement for implementation of WaterPIP-KAN project in Kenya. Report 3: "Needs Assessment of the Readiness by Small-Scale Farmers for Satellite Data to Study and Improve Water Productivity in Upper Ewaso Ng'iro Basin"; and Report 4: Training Workshop on Innovative Drip Irrigation in Upper Ewaso Ng'iro Basin, Kenya.

Report 5 responds to the project Terms of Reference (ToR) specifically, *WP1: "Taking data to the margins*". The sentinel mapping was conducted using freely available data for the year 2023. Thereafter this data was ground truth for supervised classification of NDVI using drones mounted with IR camera at two sites within the basin. Further, farmer interviews were conducted to determine types of crops grown and cropping calendars, water application were conducted at the farms visited in both Naromoru Water Resources Users Association (NaWRUA) in Laikipia County; and Elsa Water Project in Burat, Isiolo County. Both sites have small-scale farmers engaged in irrigation amid water scarcity challenges, and where improvements in water productivity of crops is desired. Also, both sites have vulnerable and marginalized communities. The main crops identified in both sites include cabbage, potato, capsicum, maize in Nawrua and onion, capsicum, tomato and maize at Elsa. The findings of the exercise are as outlined in this report.

ACKNOWLEDGEMENTS

This report was developed as part of the Water Productivity Improvement in Practice Knowledge & Action Network (WaterPIP-KAN) project, which is supported by the Directorate-General for International Cooperation (DGIS) of the Ministry of Foreign Affairs of the Netherlands under the IHE Delft Partnership Programme for Water and Development (DUPC3). AIAP team thanks the Stichting Delft Institute for Water Education (IHE-Delft) of The Netherlands, for financial support for this project.

Prof. Bancy Mati
WaterPIP-KAN Project Team Leader, at AIAP, Kenya

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1. INTRODUCTION

1.1 Background

The Association of Irrigation Acceleration Platform (AIAP) is a partner in the implementation of the international project entitled: "Water Productivity Improvement in Practice, Knowledge & Action Network (WaterPIP-KAN)". The project is funded under the *Water Development Partnership Programme (WDPP) of IHE-Delft of The Netherlands and* runs for 4 years, from November 2023 to December 2027. The other partners are from The Netherlands, Kenya, Ethiopia, Egypt, Benin, Burkina Faso and India. The WaterPIP-KAN project aims to decisively target and be inclusive of remote and marginalized communities engaged in agriculture, where improving water productivity especially under irrigation, and who constitute the grassroots beneficiaries and implementation partners of the WaterPIP-KAN project.

AIAP team previously conducted water balance modelling with remote sensing utilizing WAPOR model (in 2022) under WaterPIP-project1. During the current WaterPIP-KAN project we have upscaled by applying Sentinell-2 satellite data, and use of supervised classification utilizing NDVI obtained by flying drones mounted with IR camera over two training areas in the study area. These were further clarified through farmer interviews in the respective farms which were visited during the mapping exercise. The activities and outcomes are summarized in this report which involved mapping Major Irrigated Crops using Sentinell-II and Drones mounted with IR Camera in Upper Ewaso Ng'iro Basin, Kenya, and ground truth studies.

1.2 Introducing Sentinell-2

Sentinel-2 is an Earth observation satellite from the Copernicus Programme that systematically acquires optical imagery at high spatial resolution over land and coastal waters. The mission is a constellation with two satellites, Sentinel-2A and Sentinel-2B, which provide worldwide coverage on a five-day cycle through coordinated operation. Recently, a third satellite, Sentinel-2C, was launched in September 2024 and is expected to enhance the continuity of data acquisition, strengthen the reliability of Earth observation, and provide improved temporal resolution. the imagery obtained by the Sentinel-2 satellites supports a broad range of services and applications such as agricultural monitoring, land cover classification or water quality. Also, the high spatial resolution of 10 m, 20 m and 60 m 290 km field of view Free as well as an open data policy enable wide application of the data.

1.3 Use of Drones in crop surveillance

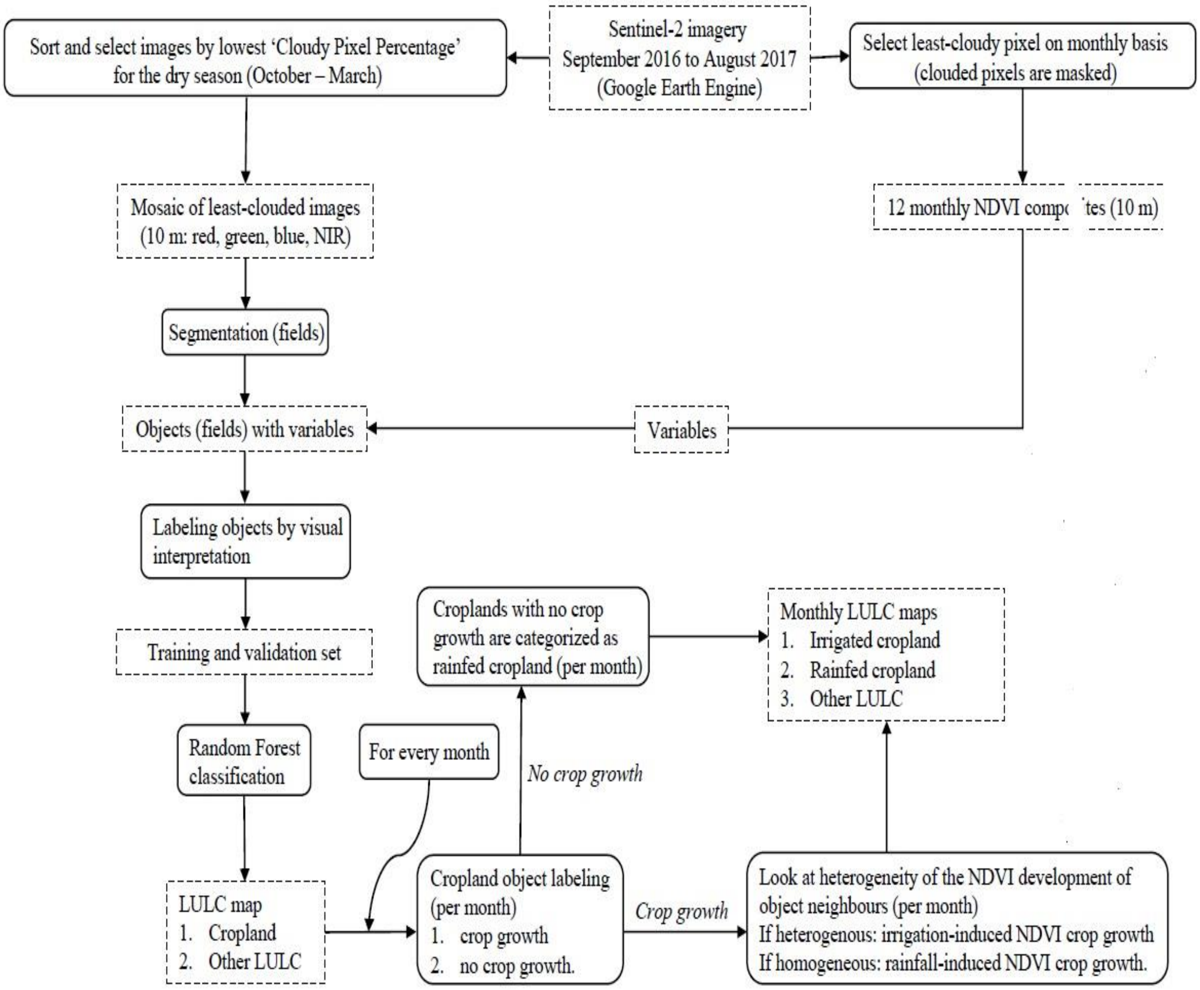
Drones, also known as Unmanned Aerial Vehicles (UAVs), Unmanned Aircraft Systems (UAS), are remotely piloted aircraft which have many applications. Compared to traditional aircraft, drones are highly cost-efficient and easy to deploy and maintain. When used for remote sensing, drones can capture high-resolution images and multispectral data even on cloudy days. In this project, small drones that can fly up to 110 m above ground were used to provide high resolution images in the infrared (IR) and Near-Infra Red (NIR) and to determine the Normalized Difference Vegetation Index (NDVI) of vegetation. The drone cameras provide real-time images for crop surveillance, to monitor plant health, optimize irrigation, and detect pests or diseases early, at least two weeks before they are visible to the human eye. They provide detailed thermal images that reveal crop stressors and other details that can't be discerned by the naked human eye. By routinely surveying agricultural fields, drones empower farmers to make informed decisions, optimize interventions and maximize overall crop yield. In this study, drones were used to fine tune NDVI values compared to satellite data, for crop identification in mapping irrigated fields.

2. REMOTE SENSING DATA APPLICATIONS

2.1 Mapping Irrigated Areas Using Sentinell-2

This project relies on the fact that irrigated agriculture can be distinguished from rainfed agriculture during the dry season. Further, it is possible to isolate the NDVI signatures of trees, grasses, bushes and other non-crop vegetation which are evergreen during the dry season. The project utilizes recent remote sensing data, preferably, satellite imagery taken in 2023, which were drought years, making it easy to isolate irrigated plots.

In this project, irrigated fields are mapped at 10 m spatial resolution using the Sentinel-2 data from the GEE Data Catalog as "COPERNICUS/ S2". The images were acquired for the dry months to coincide with main season when irrigation is commonly practiced. The satellite images were first cloud-masked using the in-built cloud mask band of Sentinel-2 Level 1C products (QA60) and clear pixels selected. Multiple vegetation indices derived NDVI, Enhanced Vegetation Index (EVI), Green chlorophyll vegetation index (GCVI), Green Index (G.I.), Soil Adjusted Vegetation Index (SAVI), Normalized difference bare index (NDBI), and Bare soil index (BSI), as well as elevation, slope, precipitation, aridity, and temperature. The figure below shows a schematic representation of the use of Sentinell-2 in isolating irrigated areas



Approach for mapping irrigated areas using Sentinell-2

The Random Forests (RF) classifier algorithm available in Google Earth Engine (GEE) is applied on the vegetation indices to map irrigated croplands. This is supervised learning technique based on the ensemble learning approach where multiple independent regression trees are generated by “bagging”, a bootstrap aggregating technique. At each regression decision tree, training samples and features are randomly selected and the optimal split feature and split point from the selected data set is determined iteratively while fitting the decision trees. In the process, *m* training sets of samples are randomly extracted from the overall dataset and used to parameterize *m* tree models. The outputs are then averaged to determine final predictions and the ensemble is evaluated using fraction of observations not used to parameterize the models as “Out-Of-Bag” (OOB) sample. To optimize the classification performance, Random Search Cross Validation is used for hyper-parameter tuning.

2.2 Use of Unmanned Aerial Vehicle (UAV)- Drones

The maps of irrigated areas are validated through field surveys and high-resolution imagery from Unmanned Aerial Vehicle (UAV)- drones. Thematic and composite maps of (all) irrigated areas will be developed. The Random Forests (RF) classifier algorithm available in Google Earth Engine (GEE) will be applied on the vegetation indices to map irrigated croplands. This is supervised learning technique based on the ensemble learning approach where multiple independent regression trees are generated by “bagging”, a bootstrap aggregating technique. At each regression decision tree, training samples and features are randomly selected and the optimal split feature and split point from the selected data set is determined iteratively while fitting the decision trees. In the process, *m* training sets of samples are randomly extracted from the overall dataset and used to parameterize *m* tree models. The outputs are then averaged to determine final predictions and the ensemble is evaluated using fraction of observations not used to parameterize the models as “Out-Of-Bag” (OOB) sample. To optimize the classification performance, Random Search Cross Validation will be used for hyper-parameter tuning. The maps of irrigated areas are validated through field surveys and high-resolution imagery from Unmanned Aerial Vehicle (UAV)- drones. Thematic and composite maps of (all) irrigated areas will be developed.

2.3 Summary of Activities Implemented

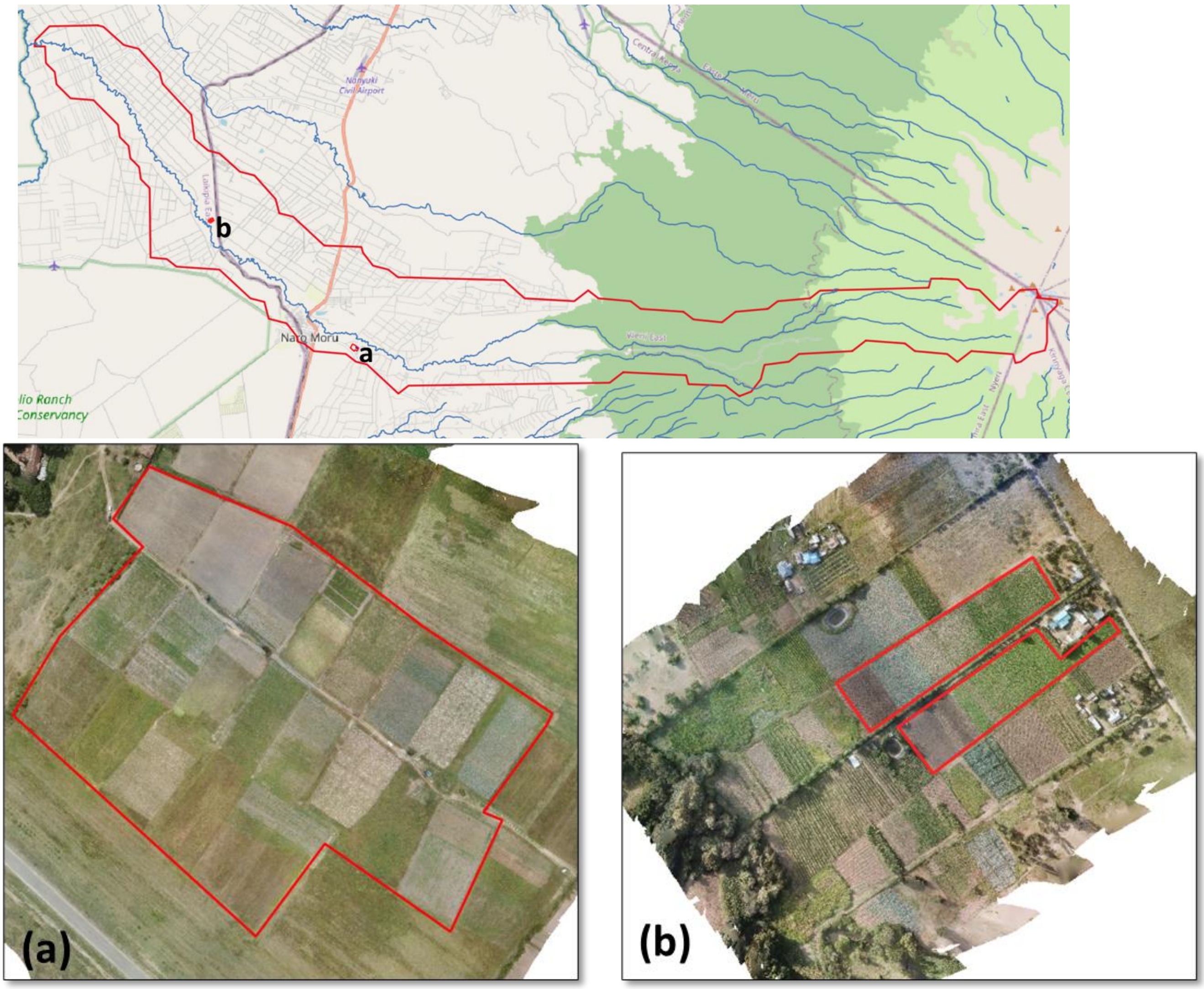
1) Desk studies and review of literature to identify areas, crops, stakeholders and other information relevant to the project areas.
2) Acquisition of remote sensing (Sentinel-2) data from online and other sources.
3) Image processing and classification of remotely sensed data from Sentinel-2 and geo-spatial data analysis and modelling as described in Section 2.4)
4) Use UAVs (drones) fitted with IR camera to capture field data in selected “Training areas”- i.e. sample sites for integrity testing and verification
5) Conducted questionnaire surveys and field visits to assess the condition of irrigated farms, crops grown, water sources, water application technologies, challenges and opportunities.
6) Preliminary analysis of combined data sets i.e. from satellite and drone, to develop spatial digital databases of Irrigated areas linked to attribute data (creating a living spatial database)
7) Preparation of this 5th Progress report.

Unmanned aerial vehicle (drone) with IR camera **The drone in flight at Rware farm, Laikipia**

3. PRELIMINARY FINDINGS

3.1 Potential for predicting crop performance and water management

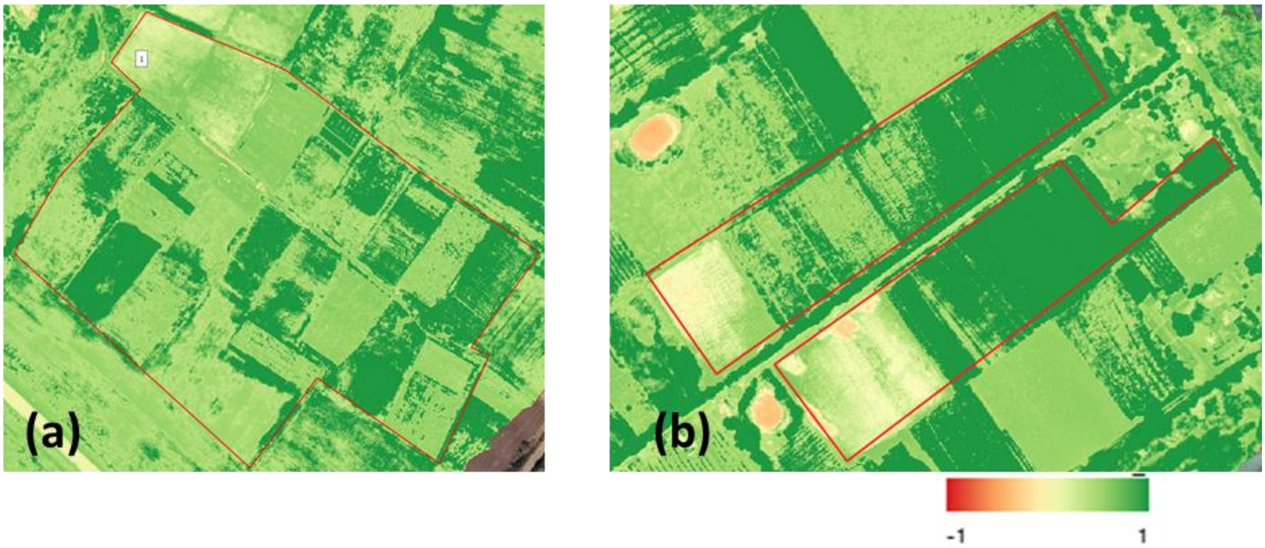
Remote sensing data have shown immense potential in identifying crop conditions and can therefore be instrumental in crop and water management. Currently, data obtained by different remote sensing platforms is being used in agriculture to identify anomalies in crops. In this field study, we focused on farmer-led irrigation focusing on different irrigation practices. The field study aimed to explore the capability of vegetation indices, computed from the Red, Green, and near-infrared bands, to detect variability at the plot scale in Naro Moru catchment. The remote sensing data were obtained using a multispectral camera mounted on an Unmanned Aerial System (UAS). Given the high spatial resolution offered by UAS, this study explores the potential of UAS to be used as a useful support information tool regarding irrigation, and agronomic management. We found that the Normalised Difference Vegetation Index (NDVI) is particularly useful for identifying non-homogeneities in irrigation and crop growth in small-scale fields.



The selected study sites considered in this field study and their location in the Naromoru catchment, (a) Rware farm, and (b) Kabuga farm

3.2 Data from Unmanned Aerial Vehicle (UAV) - Drones

The UAV data were collected during a flight conducted on June 12, 2025, under conditions of clear sky. A DJI Pro drone equipped with a RGB and IR sensor was used, which collected images having relevant spectral wavelength bands, namely Blue, Green, Red, and NIR. The UAV was autonomous and was operated respecting a pre-set flight plan corresponding to a simple grid. The UAV flight images' data, including orthorectification, atmospheric correction and elaboration of VIs maps were processed using the Pix4D software.



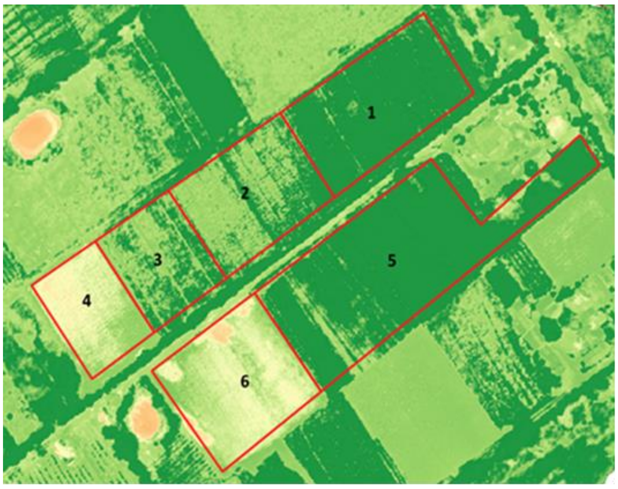
NDVI map based on UAS images showing a significant inhomogeneity

The high resolution of the UAS data offers an exceptional capability to conduct a detailed analysis of the vegetation structure within agricultural fields. This advanced spatial detail enables identification of subtle variations in crop development, plant density, and health, enabling better decision-making in crop management practices. For further analysis of US data, the NDVI was selected as the most widely used vegetation index. NDVI is a recognized index for monitoring vegetation health and biomass production which operates by exploiting the difference in reflectance between the red and near-infrared (NIR) bands of the electromagnetic spectrum, which are sensitive to plant chlorophyll content and cellular structure, respectively. NDVI ranges from -1.0 to 1.0, where positive values indicate vegetation and values near or below zero indicate non-vegetation features such as water, and bare areas.

In the two field sites under observation, certain zones showed significantly reduced NDVI values, falling within the range of approximately -0.2 to 0.2. These low values are attributed to the crops being in the initial stages of their growth cycle. During early development, crops possess minimal leaf area and limited chlorophyll content, resulting in lower reflectance in the near-infrared and higher reflectance in the red spectrum—leading to low or neutral NDVI values. On the other hand, some sites exhibited markedly high NDVI readings, which correspond to regions with thick, lush vegetation. These high-index zones are typically populated by mature crops that have developed extensive leaf cover and are undergoing active photosynthesis. The elevated NDVI values in these regions are a strong indicator of crop health, robust growth, and productive potential.

Id	Crop	NDVI mean	NDVI Min	NDVI Max
1	Onion	0.90	0.36	1.00
2	Capsicum	0.53	0.33	1.00
3	Cabbage	0.91	0.34	1.00

Figure 4: NDVI values of different crops in the Rware farm study site



Id	Crop	NDVI Mean	NDVI Min	NDVI Max
1	Capsicum intercropped with Maize	0.97	0.29	1.00
2	Capsicum	0.71	0.19	1.00
3	Cabbage	0.21	-0.28	0.63
4	Bare	0.68	0.32	1.00
5	Maize intercropped with Beans	0.94	0.16	1.00
6	Bare	0.23	-0.34	0.65

Figure 5: NDVI values of different crops in the Kabuga farm study site

In general, the spatial NDVI variability across the study sites provides a full description of crop heterogeneity of the field. This data are important in decision making for specific interventions like site-specific fertilization, irrigation, and pest management. Therefore, integration of high-resolution UAS data with vegetation indices in the study sites represents a powerful approach for modern crop monitoring and informed agricultural decision-making.

3.3 Findings from farmer interviews

3.3.1 Major crops grown

Based on interviews with farmers, the main crops grown within NaWRUA include i) cabbage, ii) capsicum, iii) maize, iv) onions, v) beans and nappier grass or other fodders. In ELSA, the main crops grown include i) cabbages, ii) capsicum, iii) maize, iv) onions, v) tomatoes, vi) beans and kales and spinach. Some farmers grow fruit trees comprising of oranges, avocadoes, mangoes, lemon and guava trees as seen in the photos herein.


A crop of capsicum at Rware farm, NaWRUA, Laikipia

3.3.2 Cropping patterns

The cropping patterns in Laikipia's NaWRUA farmers follow a three cycle routine within the year for most crops. The first pattern comprised of vegetables (Cabbages) in January followed by cereals (Maize/beans) in May and the root crops (Onions) in September. The next pattern would then comprise of Cabbages, Capsicum and French beans where these may take longer because Capsicum takes four months when harvesting starts. Other crops such as strawberries are perennial and takes about three years before it can be removed. Most farmers in Laikipia practice intercropping.

In Elsa, Isiolo County, the cropping patterns are more similar for all farmers with majority a two to three crop-seasons per year. The first cycle is the one that starts in 25th August with tomatoes followed by onions in December and Maize or Beans in April. Another cycle starts in 15th October with onions followed by tomato in February and maize or beans in June/July. Most farmers in ELSA practice relay cropping with mostly maize being introduced on an almost fully harvested tomatoes field.

Intercropping of irrigated maize and beans at Rware farm, NaWRUA

Furrow irrigation of tomato at Elsa, Isiolo

3.3.3 Challenges faced in crop farming

The main challenge expressed by all farmers was the destructive damage caused by pests especially *Tuta Absoluta* in tomatoes and thrips in onions. The larvae of Tuta absoluta feed on all parts of the tomato plant, including leaves, stems, and fruits, causing significant damage. Other pests include aphids, white-flies, fall army worms and spider mites. Crop diseases also pose problems affecting the major crops with rust and blights in leguminous crops and cereals as well as fungal diseases. Others include viral and bacterial diseases that lead to stunted growth, deformities and rots in the crops. Most of these pests and diseases are controlled with the use of pesticides and fungicides from the local agrovets outlets but can sometimes be stubborn and still damage the crop as well as constraint the farmer in terms of expected yield and the income that should otherwise be profit.

Water scarcity was the other challenge that farmers expressed especially in ELSA community where river water through the water project is rationed with one farmer receiving only five hours of water once a week. However, the farmers are enthusiastic and ensure they irrigate small portions of land with good timing for the crops to meet the market demand. Even though with good timing, there are at times prices are just low in the market during the harvest season and this poses poor returns on the expected income. Weeds are also a challenge, the farmers noted that they receive good extension services from the County officers and other private actors.

Water-stressed maize (at top) and irrigated maize below at Elsa Irrigation Scheme, Isiolo

4. WAY FORWARD

The activities described in this report are ongoing as this was a progress report. Further mapping of irrigated areas will continue through the next phase of the project. The calibration and validation of the RS data using available UAV data and ground truth studies.

Another planned activity is actual measurements of irrigation water as applied by farmers. This will help determine whether farmers are using too much, too little or enough water for irrigating major crop enterprises (cabbage onion, tomato, potato, maize, beans) . The data will also be used for calibration and developing decision support tools for use by farmers during water application. This project is working first with the water application technologies currently used by farmers. Recommendations will be made for improvements using existing irrigation infrastructure, and also suggestions for upgrading to water efficient application methods and practices that could be introduced to improve water productivity.

ANNEX 1: PARTICIPANTS DURING THE FIELD VISITS

a) Naromoru Water Resource Users Association (NaWRUA), Laikipia

S/no	Names	Gender (M/F)	Occupation/Organization
1.	Martin Macharia	M	Farmer
2.	Justin Munene	M	Naromoru WRUA
3.	Kenneth Githinji	M	Naromoru WRUA
4.	Faustine Kiogora	M	Third Eye Kenya
5.	Purity Kinya	F	Third Eye Kenya
6.	Josphat Kabuga	M	Farmer
7.	John Musau	M	AIAP
8.	Irine Jeptum	F	AIAP
9.	Betty Nyaga	F	AIAP
10.	Prof. Bancy Mati	F	AIAP

b) Elsa Water Project, Isiolo County

S/no	Names	Gender (M/F)	Occupation/Organization
1.	George Kaiyo	M	Farmer
2.	Julius Kaburu	M	Farmer
3.	Martin Mutethia	M	Farmer
4.	Charis Emmanuel	M	Farmer
5.	Mark Emalan	M	Farmer
6.	Dr. Steve Machan	M	Farmer
7.	Duncan Kimathi	M	County Agricultural Extension Services Officer
8.	Irine Jeptum	M	AIAP
9.	John Musau	M	AIAP
10.	Batty Nyaga	F	AIAP
11.	Prof. Bancy M Mati	F	AIAP