

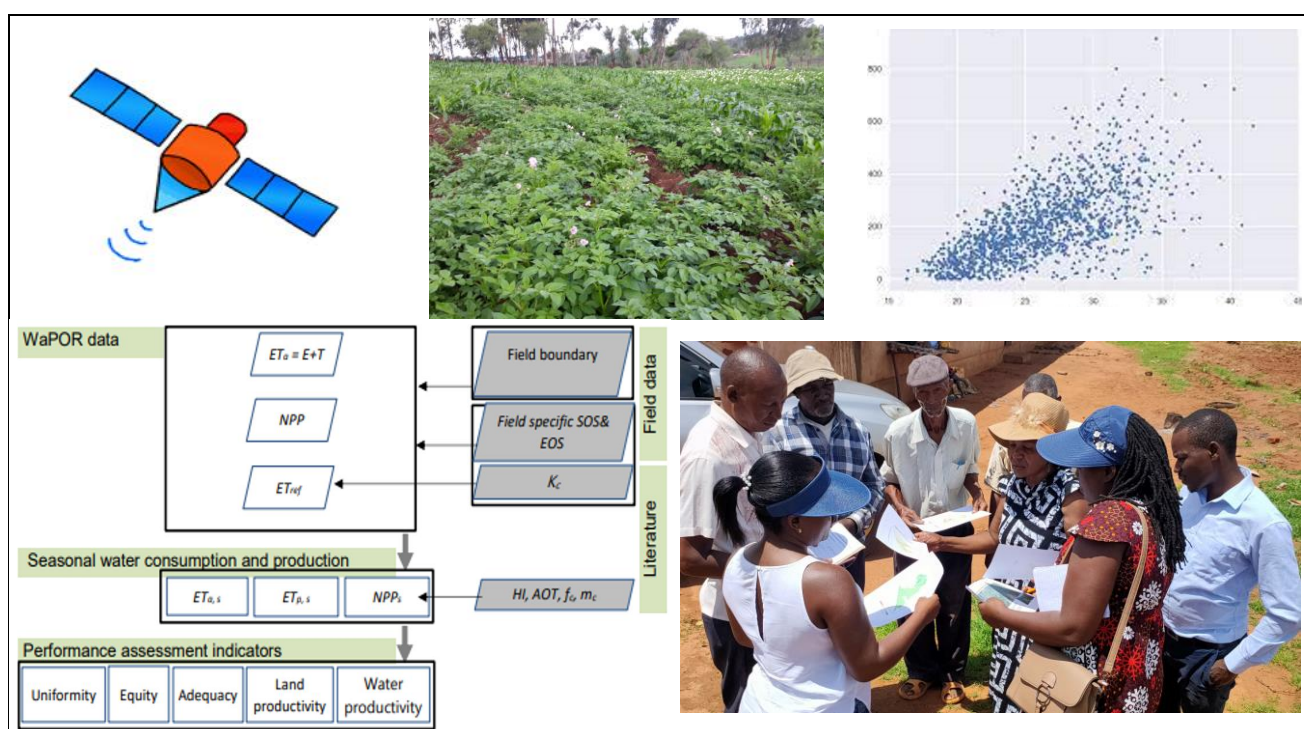


Association of Irrigation Acceleration Platform (AIAP)

WATER PRODUCTIVITY IMPROVEMENT IN PRACTICE (WaterPIP) SERVICE CENTER FOR KENYA

REPORT NO. 3

WAPOR PRODUCTS DEVELOPED BY AIAP AND STAKEHOLDER ENGAGEMENT



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Submitted to:

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ABOUT THIS REPORT

Synopsis

The Association of Irrigation Acceleration Platform (AIAP) has been working under a contract from the Stichting IHE Delft Institute for Water Education (IHE-Delft) - DUPC2 Programme, of the project *Water-PIP* top-up phase 1 (project 109065) from January to December 2022. The aim was to set up the Water Productivity Improvement In Practice (Water-PIP) Service Center for Kenya, based at AIAP. In addition, AIAP was expected to contribute to the customization of WAPOR (Water Productivity through Open access of Remotely sensed derived data) tools, by using scripts, protocols and content. Over the last 12 months, AIAP did establish the interactive WaterPIP Service Centre and worked with WAPOR data to develop products that were downscaled to users and respective services.

During the reporting period, the AIAP team downloaded and processed WAPOR data for Kenya, covering some seven (7) project sites, carefully selected where resolution of WAPOR data (100 m) could permit relatively accurate predictions of Water Productivity (WP) and yield estimations. The sites were also stratified to cover diverse crops and a wide geographical locations. The rationale for site selection, methodologies, activities, challenges and their resolution are also discussed. This project opened new ground for use of remotely sensed data grounded in local realities to develop knowledge products that can be used for future planning and to advice policy.

This is the third (3rd) and final Report submitted to IHE-Delft. It follows on the heels of two previous reports submitted earlier entitled: *“Report 1: Market analysis of remotely sensed (open data) products and services in Kenya and Report-2: Service Center Business Plan”*. This particular 3rd Report covers activities and deliverables for the period July to December 2022. It answers to Contract ToR Items (3) and (4), and proves that AIAP fulfilled and exceeded the set targets.

A logical criteria was used in the selection of field sites for WAPOR simulation, taking into account the model's low resolution of 100 m, and the possibility of acquiring clients for WAPOR data. This culminated in identification of seven (7) field sites in Kenya for which the model was successfully applied. The sites are: Mwea, Kibirichia, Kibwezi, Ramisi, Perkerra, Ahero and West Kano. Then methodologies were developed and used for WAPOR simulation to produce downscaled data, maps and field level results. A total of 497 individual output maps were produced for the 7 sites respectively. The maps capture quantified data on five variables, viz: water productivity, biomass production, crop yield prediction, adequacy and beneficial fraction of irrigation water. The map data were further verified through field visits to Mwea, Kibirichia, Kibwezi and Ramisi. There is evidence that AIAP provided more than 5 services as the WaterPIP service Center for Kenya.

Towards promoting use of WAPOR data, AIAP held over six (6) events to promote WAPOR (ToR required at least 3 events), which included workshops, training events and meetings with at least 62 stakeholders. A dedicated WaterPIP web domain (<https://aiap.or.ke/index.php/waterpip/>) was created for sharing data, articles and information, thus publicizing WAPOR widely. Although there were challenges e.g. low resolution of WAPOR data, generally, AIAP delivered on the project ToRs.

This report has six chapters, namely: (1) Background; (2) Downscaling WAPOR Data to Kenyan contexts; (3) Results: WAPOR Products Developed for Target Field Sites; (4) Events to Promote WAPOR and Dissemination of Information; (5) Conclusions and Lessons Learnt; and (6) Annexes.

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Table of Contents

ABOUT THIS REPORT.....	i
LIST OF ACRONYMS AND ABBREVIATIONS	iv
1. BACKGROUND	1
2. DOWNSCALING WAPOR DATA TO KENYAN CONTEXTS	2
2.1 Site selection for WAPOR data modelling	2
2.1.1 Criteria for Selection of Target Sites/Clients for WAPOR	2
2.1.2 Characteristics of the Selected sites for WAPOR simulation	3
2.2 Identifying useful products from WAPOR data.....	3
2.2.1 Water productivity.....	3
2.2.2 Crop Biomass.....	4
2.2.3 Crop yield prediction	4
2.3 Steps in determining irrigation performance from WAPOR Data	4
2.4 Limitations of WAPOR data.....	5
3. RESULTS: WAPOR PRODUCTS DEVELOPED FOR TARGET FIELD SITES	6
3.1. Location of Field sites where WAPOR data was simulated	6
3.2 WAPOR simulation databases developed	7
3.3 Products developed from WAPOR simulation for each field site	8
4. EVENTS TO PROMOTE WAPOR AND DISSEMINATION OF INFORMATION.....	16
4.1 Organizing and implementing promotional events	16
4.2 Institutional and capacity strengthening activities	17
4.3 Dissemination of WAPOR products to stakeholders & events reports.....	17
4.3.1 Promotional events implemented at Mwea Irrigation Scheme	17
4.3.2 Visit to Meru County offices and Kibirichia farmers.....	18
4.3.3 Visit to Chumani and Rea Vipingo sisal estate in Kibwezi.....	19
4.3.4 Meeting at Msabweni sub-county office and visiting Ramisi sugar plantation	20
4.4: Service Center Interactive knowledge sharing through ICT	21
4.4.1 WaterPIP portal hosted by AIAP.....	21
4.4.2 GitHub Repository	22
4.4.3 Machine learning scripts.....	22
5. CONCLUSIONS AND LESSONS LEARNT	23
5. ANNEX 1- LIST OF STAKEHOLDERS MET TO PROMOTE WAPOR	25
5.1 List of participants at Mwea starter meeting held on 19 th January 2022	25
5.2 List of stakeholders met during field visit to Mwea on 17 th November 2022	25
5.3 Stakeholders met at Meru County Office and Kibirichia on 18 th November 2022	26
5.3 List of stakeholders met in Kibwezi on 24 th November 2022	26
5.4 Stakeholders met at Msabweni and Ramisi 25 th November 2022.....	26

LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Full name/ meaning
AIAP	Association of Irrigation Acceleration Platform
ASAL	Arid and Semi-Arid Lands
CBO	Community-Based Organization
DEM	Digital Elevation Model
EM	Electromagnetic Spectrum
ET	Evapotranspiration
FAO	Food and Agricultural Organization of the United Nations
GIS	Geographic Information Systems
GoK	Government of Kenya
Ha	Hectare
ICT	Information, Communication Technologies
IHE-Delft	Stichting IHE Delft Institute for Water Education (of the Netherlands)
IWUA	Irrigation Water Users Association
KALRO	Kenya Agricultural and Livestock Research Organization
MIAD	Mwea Irrigation and Agricultural Development center
MIS	Mwea Irrigation Scheme
MWS&I	Ministry of Water, Sanitation and Irrigation
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NIA	National Irrigation Authority
NIR	Near InfraRed
NPP	Net Primary Production
O&M	Operation and Maintenance
OSAVI	Optimized Soil Adjusted Vegetation Index
RS	Remote sensing
SAVI	Soil Adjusted Vegetation Index
SME	Small and Medium-Sized Enterprise
SSI	Small Scale Irrigation
UAS	Unmanned Aerial Systems
WAPOR	Water Productivity through Open access of Remotely sensed derived data
WaterPIP	Water Productivity Improvement In Practice

1. BACKGROUND

The Association of Irrigation Acceleration Platform (AIAP) is the designated Service Center for “Water Productivity Improvement in Practice (WaterPIP)” in Kenya. The Center was established through a one-year project, beginning December 2021 to December 2022, with funding from the Stichting IHE Delft Institute for Water Education (IHE-Delft) – under the DUPC2 Programme. Now in December 2022, the WaterPIP Service Center has been established and is operational. In addition, the project team has been working with WAPOR (Water Productivity through Open access of Remotely sensed derived data) to produce outputs/deliverables that are in usable formats. The WaPOR tools by FAO¹ provide unique open data resources to assist in research, innovation and decision making to transform productivity. The products developed by AIAP can be used to advance the cause for improved water productivity as well as for advising policy and agricultural water experts and ultimately, farmers in Kenya.

In fulfilment of project reporting, AIAP has previously submitted two project reports to IHE-Delft, namely; *Report 1: Market analysis of remotely sensed (open data) products and services in Kenya;* and *Report 2: Service enter Business Plan*. This particular report is the third and final one by AIAP. It describes the progress made, activities implemented and deliverables produced with special focus on contract items (3) and (4) of the agreement between AIAP and IHE-Delft.

During the reporting period, the AIAP team downloaded and processed WAPOR data for Kenya, covering some seven project sites carefully selected where the resolution of WAPOR data (100 m) could permit relatively accurate predictions of Water Productivity (WP) and yield estimations. The sites were also stratified to cover diverse crops and a wide geographical locations. The rationale for site selection, methodologies, activities, challenges and their resolution are also discussed. In addition, AIAP implemented a number of activities to promote use of WAPOR and promote it widely to users. This project opened new ground for use of remotely sensed data grounded in local realities to develop knowledge products that can be used for future planning and to advice policy.

From the foregoing, the AIAP team has successfully delivered knowledge products and services designed to improve water productivity of agricultural enterprises in Kenya. This has included among others: customization of WaPOR tools (scripts, protocols, content) developed by the WaterPIP project team to local contexts, downscaling WAPOR data into Kenyan contexts, facilitating knowledge transfer to users in form of data, information, maps and content, as well as explaining its meaning to stakeholders. These components are covered in this report.

¹ <http://www.fao.org/in-action/remote-sensing-for-water-productivity/wlpa-introduction/wapor-applications/measuring-water-productivity/en/>

2. DOWNSCALING WAPOR DATA TO KENYAN CONTEXTS

This component responds to Item (3) of AIAP's Terms of Reference (ToR), which stipulates that the service center should ensure throughout the period of the assignment compile proof of that at least 5 different services that have been provided, either to different stakeholders or in different geographies. These services and evidence thereof should include: (i) clear reason and rationale for the service (what is the service addressing), (ii) a description of the service (methodology and tools used and outputs delivered); and (iii) as well as a clearly described user experience, i.e. how has the service been of (added) value to the centers. All these were done albeit WAPOR has low spatial resolution of 100 m, which posed challenges when applied to Kenyan agricultural landscapes which are dominated by small-scale mixed cropping. To address this challenge, criteria was developed for site selection, then suitable sites in Kenya identified where WAPOR was applied.

2.1 Site selection for WAPOR data modelling

In identifying field sites to apply WAPOR data in Kenya, a number of considerations were made, including scale, the low resolution of the RS data, crop type and prospects for utility of the downscaled products for decision making. For this reason, WAPOR data is better deployed in large irrigation schemes or large estates growing a monocrop, for the outputs to be highly correlated with the actual crop on the ground. It was also necessary to stratify the location of the sample sites geographically across the country. For this reason, WAPOR was applied to some seven (7) large scale farmlands across Kenya identified using the following criteria:

2.1.1 Criteria for Selection of Target Sites/Clients for WAPOR

The criteria used in the selection of field sites to apply WAPOR data included:

- Areas under large-scale irrigation due to scale issues and utility of outputs;
- Areas with a specific crop enterprise (preferably monocrop) to get a single signature;
- The irrigation schemes and/or rainfed crop that cover relatively large contiguous area;
- The presence of at least one institution that can be approached as a client;
- The opportunity to leverage data on water productivity using remotely sensed data;
- Possible demand for WAPOR products in the selected site (hence client);
- Diversity in the types of crops assessed for water productivity using WAPOR; and
- Geographic stratification to cover various zones and crops in Kenya.

Using these criteria, a starter set of ten (10) field sites were identified across Kenya. The idea was to run the model for a wide set of possible clients, so that the minimum of 5 clients stipulated in the contract could be attained. But trial runs using WAPOR model failed to produce good results for three sites, namely: Kitale (rainfed maize), Katilu irrigation Scheme in Turkana County (irrigated maize) and Molo sub-county of Nakuru County (rainfed potato). This was because there was too much "noise" in the simulated data, rendering the outputs unusable. These three field sites were dropped. The remaining seven (7) sites were taken to the next stage of WAPOR modelling. These field sites are described below.

2.1.2 Characteristics of the Selected sites for WAPOR simulation

Based on the criteria described above, some seven (7) Field sites in Kenya were used for WAPOR simulation with good results. Table 2 shows a summary of the field site name, its location, major crop grown, possible clients for WAPOR and other comments.

Table 2: Field sites, their location, major crop grown and possible clients for WAPOR data

SNo	Field Site	County	Major crop	Possible client	Comments/ Opportunity
1.	Mwea Irrigation Scheme	Kirinyaga	Irrigated rice (Basmati)	MIAD (Research Center) & NIA	Provide data to support Mwea's Strategy for improving WUE
2.	Kibirichia Sub-County	Meru	Irrigated potatoes	Meru County Government	Work with small-scale rainfed and irrigated farming systems
3.	Kibwezi area	Makueni	Rainfed Sisal	Makueni County Government & Rea Vipingo	Promote small-scale sisal farming as a drought tolerant, climate-smart crop
4.	Ramisi/Msabweni area	Kwale	Irrigated sugarcane	Kwale County Government & KISCOL	Offer WP data on irrigated sugar farming at the coast
5.	Perkerra Irrigation Scheme	Baringo	Seed maize	Baringo County Government & Kenya Seed Company	Promote small-scale irrigated maize for seed
6.	Ahero Irrigation Scheme	Kisumu	Irrigated rice (IR variety)	Western Kenya Schemes & NIA	Provide data to support Ahero's Strategy for improving WUE
7.	West Kano Irrigation	Kisumu	Irrigated rice (IR variety)	Western Kenya Schemes & NIA	Provide data to support West Kano's Strategy for improving WUE

2.2 Identifying useful products from WAPOR data

WAPOR provides a range of products that are useful for informing decision on water allocation especially for irrigated agriculture. In determining water productivity, integration of remote sensing imagery and crop modelling tools were used. Data were obtained from open access databases providing spatial information on water productivity, water consumption, or land cover classification. These were downscaled to respective field sites providing quantified data on; water productivity, biomass production, crop yield prediction, adequacy (relative evapotranspiration), and beneficial fraction of irrigation water. These values were determined as follows:

2.2.1 Water productivity

Water productivity is a robust measure that can be applied at different scales to suit the needs of different stakeholders. Water productivity is achieved by defining the inputs of water and outputs in units appropriate to the users' indicator needs. The numerator (output derived from water use) can be defined in the following ways: Physical output, which can be total biomass or harvestable product; and Economic output (the cash value of output) either gross benefit or net benefit. The

water input can be specified as volume (m^3) or as the value of water expressed as the highest opportunity cost in alternative uses of the water, (Cook, et al., 2006). Different indicators could be used to assess water productivity for a cropping system at different scales. Due to the low resolution of WAPOR data (100 m, this project adopted the Irrigation system scale in determining the water productivity of monocrops in relatively large areas where irrigation is practiced in Kenya.

2.2.2 Crop Biomass

Biomass is an important indicator for evaluating crops. Quick, accurate and nondestructive monitoring of biomass is the key to smart agriculture and precision agriculture. Wang, et al., (2021), points out that satellite remote sensing, manned airborne equipment, and vehicle-mounted equipment can nondestructively collect measurements, but are limited by low accuracy, poor flexibility, and high cost. Therefore a nondestructive remote sensing equipment with high precision, high flexibility, and low-cost, unmanned aerial systems (UAS) are suitable for monitoring crop biomass. These utilize vegetation indices such as normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), optimized soil adjusted vegetation index (OSAVI), and crop height are the commonly used biomass monitoring methods. Biomass production was calculated from the decadal net primary production data layer from WAPOR.

2.2.3 Crop yield prediction

Yield prediction is an important aspect in the agricultural economics value chain. Using WAPOR data and biomass calculations the crop yield per water consumed can be calculated. The Above Ground Biomass Production (AGBP) is the ultimate indicator to express food production. The WAPOR database contains information on Above Ground Biomass Production (AGBP) based on the Net Primary Production (NPP).

2.3 Steps in determining irrigation performance from WAPOR Data

The methodology adopted in developing these products is summarized in Figure 1. More specifically, it entailed deriving the irrigation performance indicators were from WaPOR and field data using the following eight steps:

- 1) The following layers of FAO WaPOR datasets were obtained: Actual Evapotranspiration & interception (AETI), Transpiration (T), Net Primary Production (NPP), Precipitation (PCP) and Reference Evapotranspiration (RET)
- 2) The precipitation (P) and reference evapotranspiration (RET) datasets were resampled to 100 m resolution using the nearest-neighbor resampling techniques to match the other layers
- 3) All WaPOR layers were masked using boundary of the irrigated area
- 4) Field data on start and end of crop season as well as monthly crop coefficient (K_c) was used to calculate seasonal AETI, T, NPP, RET and seasonal potential evapotranspiration ($ET_p = RET \times K_c$).
- 5) Seasonal NPP was translated to above-ground biomass using crop-specific information (above over total biomass (AOT) for non-root crops or below over total for root and tuber crops, light use efficiency correction factor (f_c), and moisture content of fresh biomass (mc) following Mul

and Bastiaanssen (2019). Adequacy was calculated to assess the degree of agreement between the actual water use and crop water requirement.

- 6) Crop yield was derived by multiplying crop above-ground biomass by crop-specific harvest index (HI)
- 7) The following irrigation performance indicators were then computed, for each site:
 - a. Uniformity (coefficients of variation of seasonal ET for the field, CV of 0 to 10% is good, 10 to 25% is fair and CV > 25% is poor uniformity (Bastiaanssen et al., 1996).
 - b. Beneficial fraction (the ratio of the water that is consumed as transpiration compared to overall field water consumption (ETa))
 - c. Adequacy (the ratio of actual ET to potential ET)
 - d. Crop Biomass Productivity, kg/m^3 ((biomass/AETI)*100)
 - e. Crop yield Productivity, kg/m^3 ((Yield/AETI)*100)

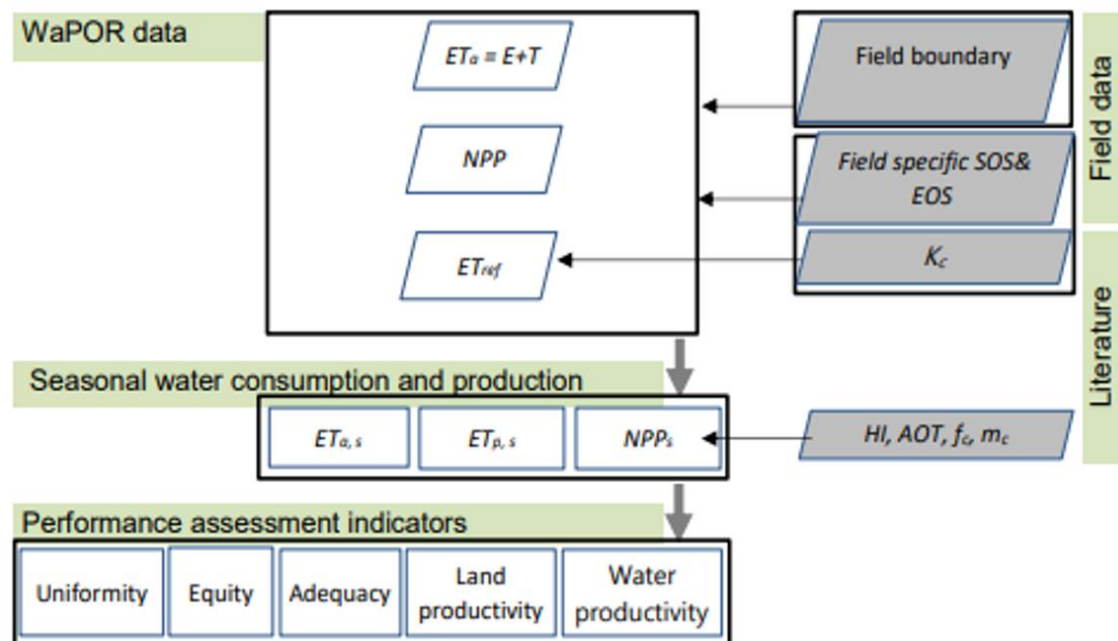


Figure 1: Schematic representation of WaPOR based Irrigation performance assessment framework

- 8) Using the maps and data derived from this process, the findings were validated through field visits and discussions with stakeholders, including leaders and farmers. This was done at four field sites, namely: Mwea, Kibirichia, Kibwezi and Ramisi. Two sites; Ahero and West Kano were visited during the mapping process and were thus validated using recorded data.

2.4 Limitations of WAPOR data

A major limitation of was the low resolution of WAPOR data (100 m). This was overcome by selecting *areas* having large-scale irrigation. Thus, it was not possible to apply WAPOR to small-scale irrigation and multiple cropping systems. The translation of WP into yield was difficult for fruits e.g. citrus, banana. It was difficult to predict certain variables that affect production such as, water allocation, crop varieties, adaptability, soil degradation, water scarcity and drought.

3. RESULTS: WAPOR PRODUCTS DEVELOPED FOR TARGET FIELD SITES

This component responds to Items 3 & 4 of AIAP's ToR, describing the types of WAPOR products developed by the Center. This offers proof that some seven (7) different products were provided to different stakeholders at different geographies. This chapter describes the WAPOR outputs delivered, showing how these added value to respective possible clients and stakeholders.

3.1. Location of Field sites where WAPOR data was simulated

It was necessary to prove that WAPOR data is applicable to Kenya, and also to develop products for sharing with stakeholders who may not be well versed with remote sensing and modelling tools. Thus, AIAP developed value-added products based on WAPOR databases. These products and services include user-oriented information and maps, culminating in yield data predictions for various crops in specified areas as presented in Table 2. Results of WAPOR modelling are thus available for seven (7) field sites in Kenya (Figure 2) for which the model was simulated.

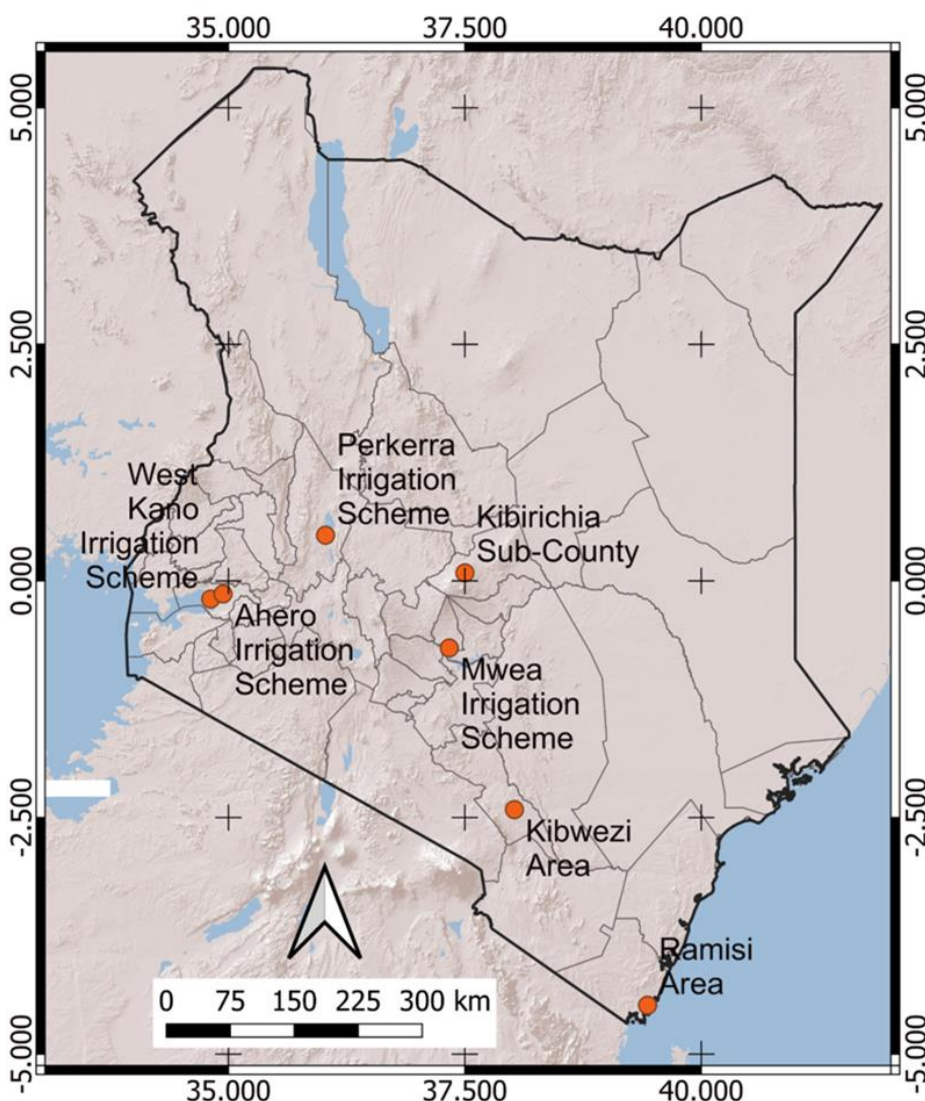


Figure 2: Location of the seven field sites in Kenya for which WAPOR was simulated

3.2 WAPOR simulation databases developed

This project identified and developed sets of five products that were derived using WAPOR tools for Kenya. They include water productivity of specific crop enterprises with further processing as explained in section 2.3. Some five distinct WAPOR products were developed for each site, viz:

- (i) Water productivity (WP);
- (ii) Biomass production;
- (iii) Crop yield prediction;
- (iv) Adequacy of the water provided to crop; and
- (v) Beneficial fraction of irrigation water in relation to water availed to the crop.

A summary of the WAPOR data downscaled across the seven field sites is provided in Table 3.

Table 3: Summary of WAPOR downscaled datasets for the 7 Field sites, in Kenya

SNo	Field Site	County	Major crop	WAPOR processed data	Years simulated
1.	Mwea Irrigation Scheme	Kirinyaga	Irrigated rice (Basmati)	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction (scale of 0-1) Above ground biomass (t/ha) Crop yield (t/ha)	2016 - 2021 2016 - 2021 2016 - 2021 2009 - 2021 2016 - 2021
2.	Kibirichia Sub-County	Meru	Irrigated potatoes	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Above ground biomass (t/ha) Beneficial fraction (scale of 0-1) Crop yield (t/ha)	2016 - 2021 2016 - 2021 2016 - 2021 2016 - 2021 2016 - 2021
3.	Kibwezi area	Makueni	Rainfed Sisal	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction (scale of 0-1) Above ground biomass (t/ha) Crop yield/biomass (t/ha)	2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021
4.	Ramisi/Msabweni area	Kwale	Irrigated sugarcane	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction Crop yield/biomass (t/ha)	2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021
5.	Perkerra Irrigation Scheme	Baringo	Seed maize	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction (scale of 0-1) Above ground biomass (t/ha) Crop yield (t/ha)	2009 - 2021 2009 - 2021 2009 - 2021 2009 - 2021 2009 - 2021
6.	Ahero Irrigation Scheme	Kisumu	Irrigated rice (IR variety)	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction (scale of 0-1) Above ground biomass (t/ha) Crop yield (t/ha)	2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021
7.	West Kano Irrigation	Kisumu	Irrigated rice (IR variety)	Water Productivity (kg/m ³) Adequacy (scale of 0-1) Beneficial fraction (scale of 0-1) Above ground biomass (t/ha) Crop yield (t/ha)	2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021 2011 - 2021

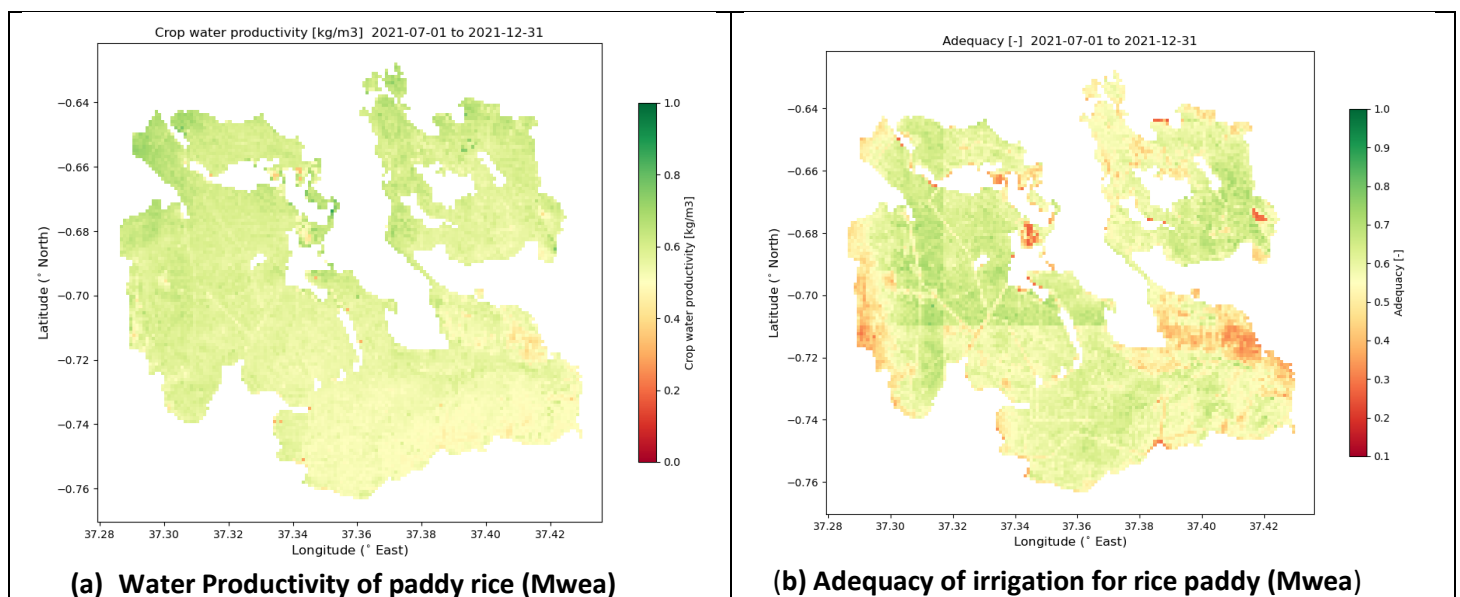
3.3 Products developed from WAPOR simulation for each field site

From Table 3, by considering all the variables, for all the years, across the seven field sites, it is apparent that a total of 497 individual maps/datasets were created. It is not possible to show all these datasets. Thus, in this report, we show a sample utilizing data for the year 2021 across all the field sites. This enables easier comparison and interpretation of results.

The year 2021 was selected because it was generally dry with less than normal rainfall recorded throughout the country. This offers opportunity to assess the utility of WAPOR as a predictor for irrigated agriculture for rice, potatoes and sugarcane, as well as for sisal as a rainfed crop. These maps are presented here as follows:

1) Results of simulated by WAPOR data for Mwea Irrigation Scheme

Mwea Irrigation Scheme (MIS) is the largest rice growing scheme in Kenya. The Scheme utilizes large volumes of water for the flooded paddies. MIS has a Strategic Plan which has listed improving water use efficiency (WUE) as a core objective. However, the scheme management does not have a system for tracking WUE improvements. Farmers in the scheme have been trained on the system of rice intensification (SRI) which utilizes less water. A tool like WAPOR can help track where WUE or WP has improved. Figure 3 presents the values from WAPOR simulation respectively for; Water Productivity, Adequacy, Biomass and crop (grain) yield for the year 2021. The farmers reported an average crop yield of 4.5 to 5 t/ha/season which is comparable to the values obtained from the WAPOR data (4.1 t/ha/season) shown in Figure 3(d). The spatial spread of water productivity is explained by the fact that water scarcity was experienced in areas towards the lower end of the scheme in 2021.



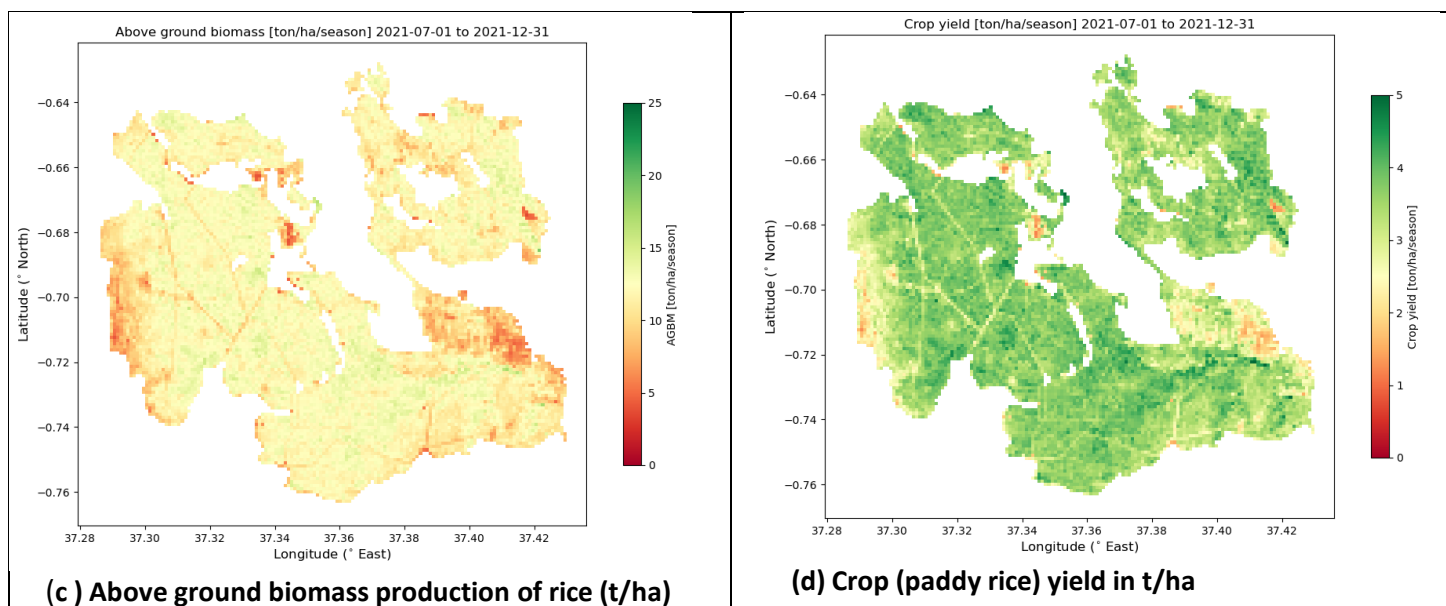


Figure 3: Simulated WAPOR outputs for Rice paddy at Mwea Irrigation Scheme for 2021

2) Results of simulated by WAPOR data for potato crop at Kibirichia

Kibirichia sub-county lies on the upper footslopes of Mt. Kenya. Due to high altitude, the area is cool albeit rather dry as it lies on the lee sides of the mountain. Irrigation is therefore a necessity and most farmers practice irrigation on small and medium scale farms, growing horticultural crops like Potatoes, cabbage, garden peas and sugar snaps. Potatoes are the most dominant irrigated crop, which is sometimes grown rainfed, and was thus selected as the test crop for WAPOR modelling. Although these are disjointed small scale farms, the crop units are large enough for applicability of WAPOR data. Figure 4 presents the values from WAPOR simulation respectively for; Water Productivity, Adequacy and crop (potato) yield for the year 2021.

During the field visit, farmers in Kibirichia reported 10 t/ha/season as the average yield per season for potatoes which is comparable to the yield values obtained from WAPOR data. One of the key challenges in the processing of the WAPOR data for this area concerns land cover classification for identification of different crop types. Unlike in the Mwea irrigation scheme where a single crop is grown, in this area multiple crops are cultivated leading to mixed signals in the WAPOR data. In addition, variations in the planting calendar may influence the accuracy of the results for this area.

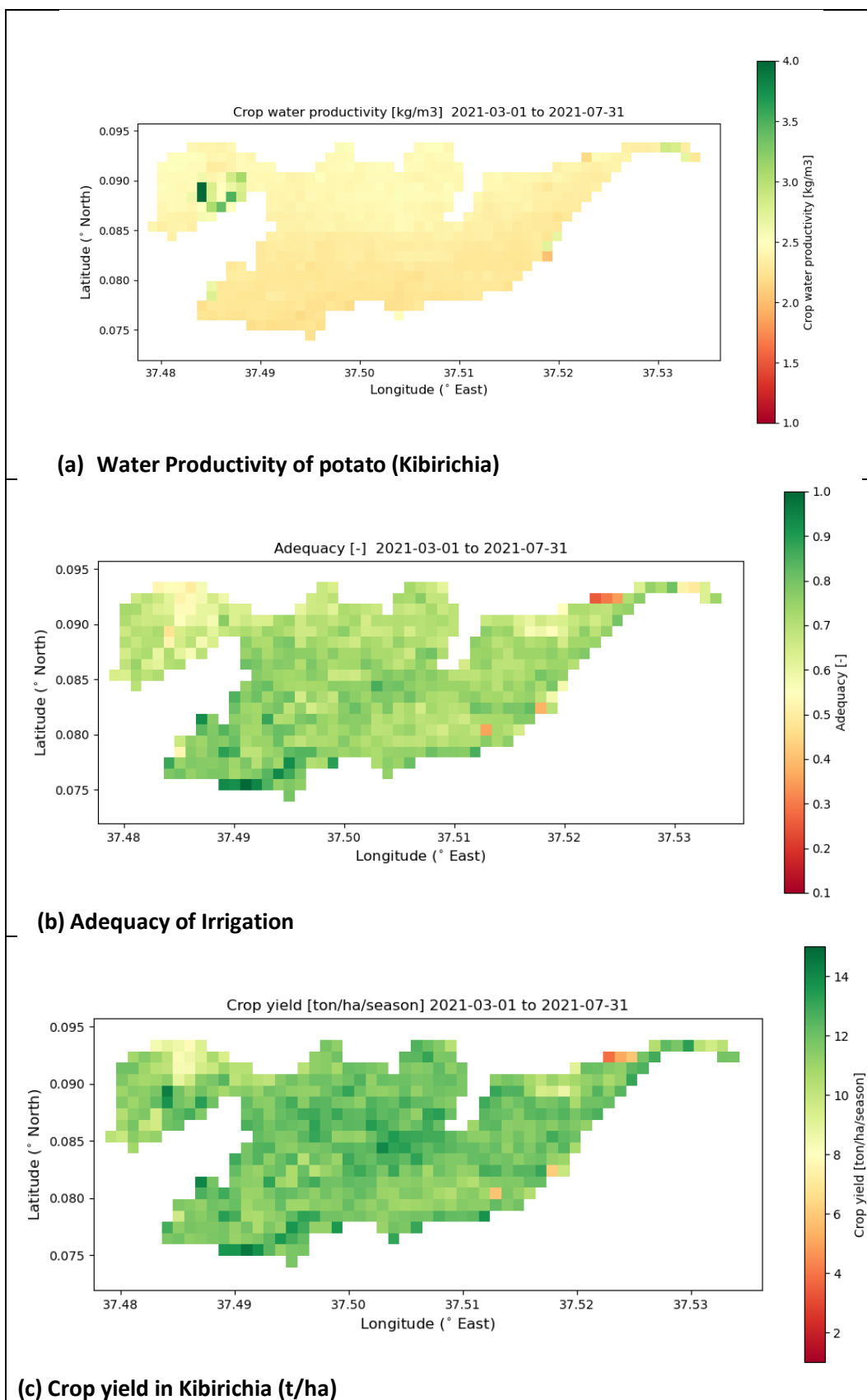


Figure 4: Simulated WAPOR outputs for potatoes at Kibirichia, Meru for 2021

3) Results of simulated by WAPOR data for sisal at Kibwezi

Kibwezi is located in Makueni County in a semi-arid zone, where seasonal rainfall is low (annual rainfall is 600 mm). The local people are small-scale farmers growing maize, green grams and pigeon peas for food. But rainfall is erratic and droughts occur regularly resulting in severe food insecurity. Between 2021 and 2022, a lengthy drought hit the area and there were no crops harvested for 2 years. However, the large scale sisal plantation continued to thrive even in the worst of droughts. Yet the neighboring farmers do not grow sisal as a cash crop except as a hedge to mark farm boundaries. Sisal is a hardy fiber crop that thrives in dry zones even on relatively poor soils and requires less labor and farm inputs as compared to field crops. It is for this reason Kibwezi was chosen as a field site for WAPOR simulation, in an effort to popularize sisal production as a cash crop with multiple benefits, which include: cash incomes for farmers. It is a climate-smart fiber crop to support reduction of plastics use among others. The results of WAPOR simulation (Figure 5b) agree with values (15 t/ha/year) obtained from the sisal plantation.

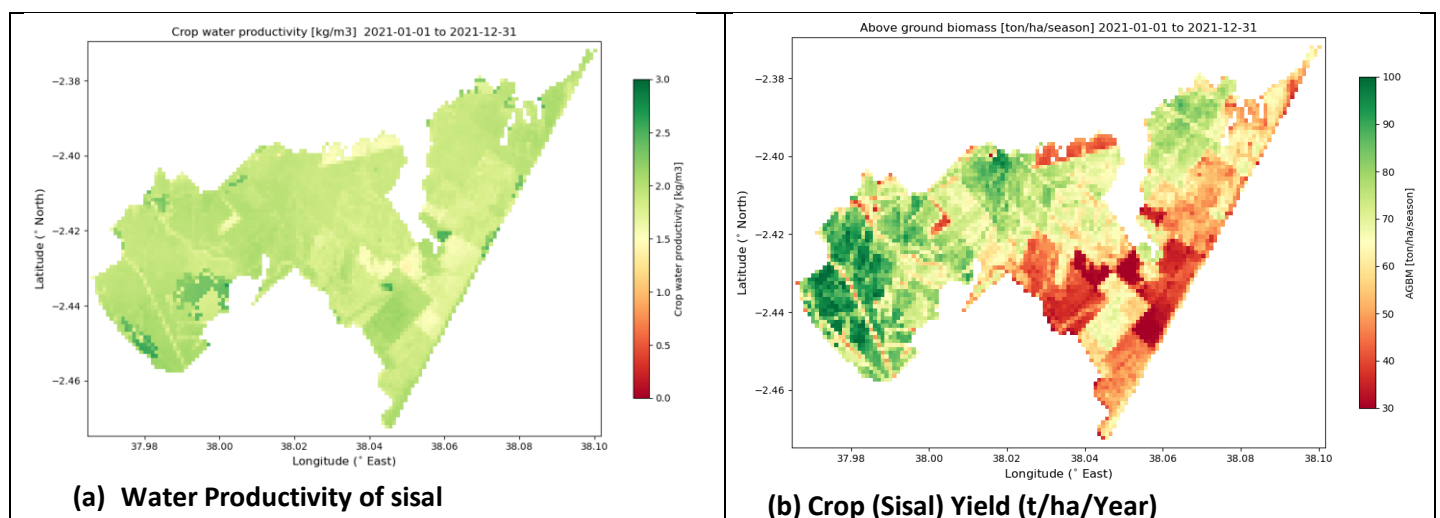


Figure 5: Simulated WAPOR outputs for sisal at Kibwezi for 2021

4) Results of simulated by WAPOR data for sugarcane at Ramisi

Ramisi area in Kwale County has a large scale estate, KISCOL where irrigated sugarcane is practiced. The estate also engages out-growers in surrounding areas. Ramisi has both rainfed and irrigated sugarcane (unlike western Kenya where all the sugarcane is rainfed). Generally, sugarcane requires 1,500 mm/year of rain (Ramisi receives about 1,100 mm), meaning that although rainfed sugar will grow around Ramisi, the crop suffers moisture stress during the dry season and thus requires irrigation. The coastal region has substantive land and water potential for out-scaling irrigated sugar production. Thus use of WAPOR data holds promise for supporting policy decisions to expand irrigated sugar production at the Coast. It is for this reason Ramisi was chosen as a field site for WAPOR simulation. The crop yield values obtained from WAPOR data (Figure 6c) are comparable to the values (120 t/ha/year) obtained from the sugar estate. From our results, the water productivity indices varied significantly across the irrigation scheme which indicates low uniformity and inadequacy of the water received by the crop. Other factors may also influence the water productivity including soil characteristics as well as difference in the varieties of sugarcane grown in the scheme.

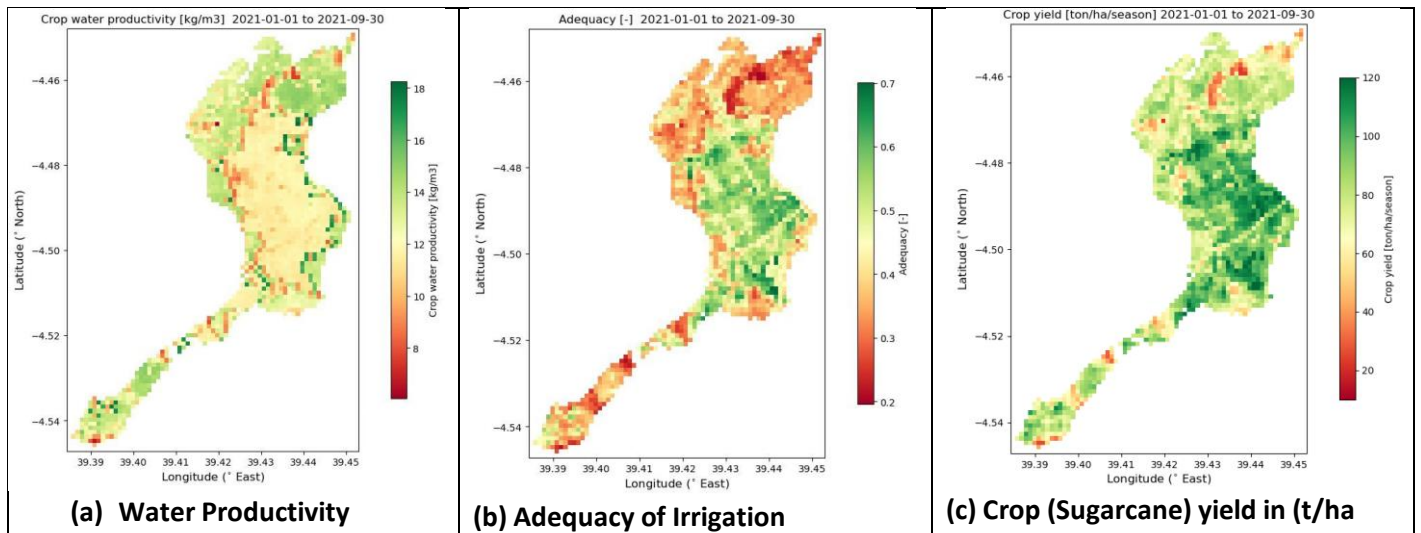
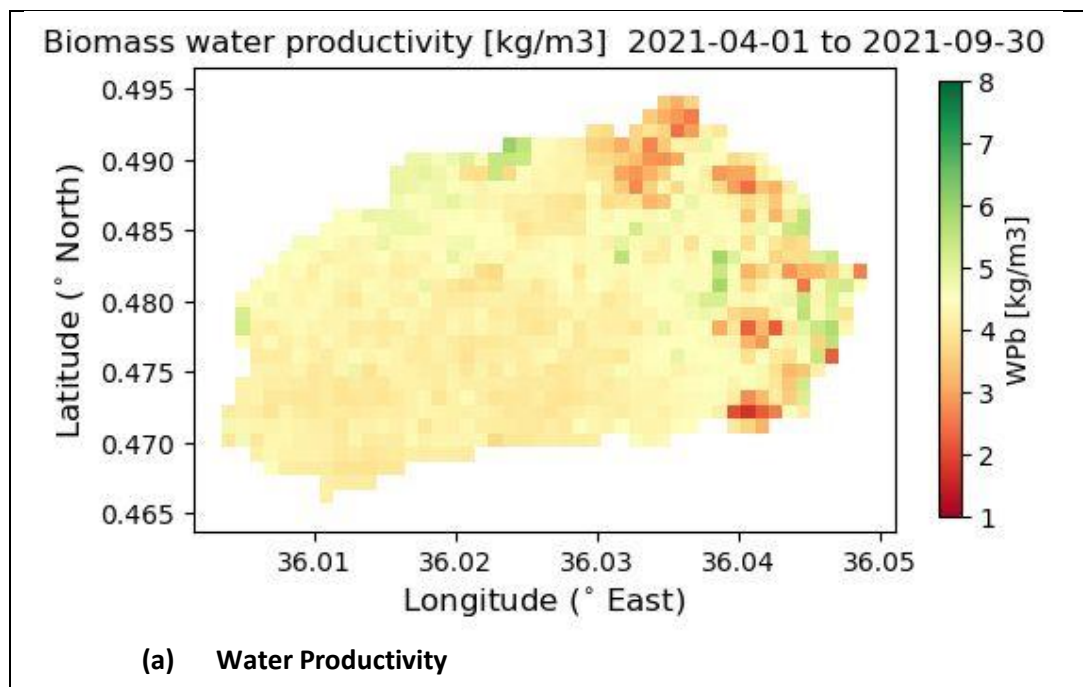


Figure 6: Simulated WAPOR outputs for sugarcane at Ramisi for 2021

5) Results of simulated by WAPOR data for seed maize at Perkerra

Perkerra Irrigation Scheme is situated in Baringo South Sub-County. The scheme hosts small-scale farmers who grow a variety of crops, but seed maize is the predominant cash crop. The seed maize is grown under contract from Kenya seed company, a possible client for WAPOR data. It was thus possible to get remote sensing data for large areas for maize at Perkerra, the reason the field site was selected for WAPOR simulation. The results of WAPOR simulation (Figure 7) for seed maize at Perkerra Irrigation Scheme agree with values (4.9 t/ha/season) obtained from records.



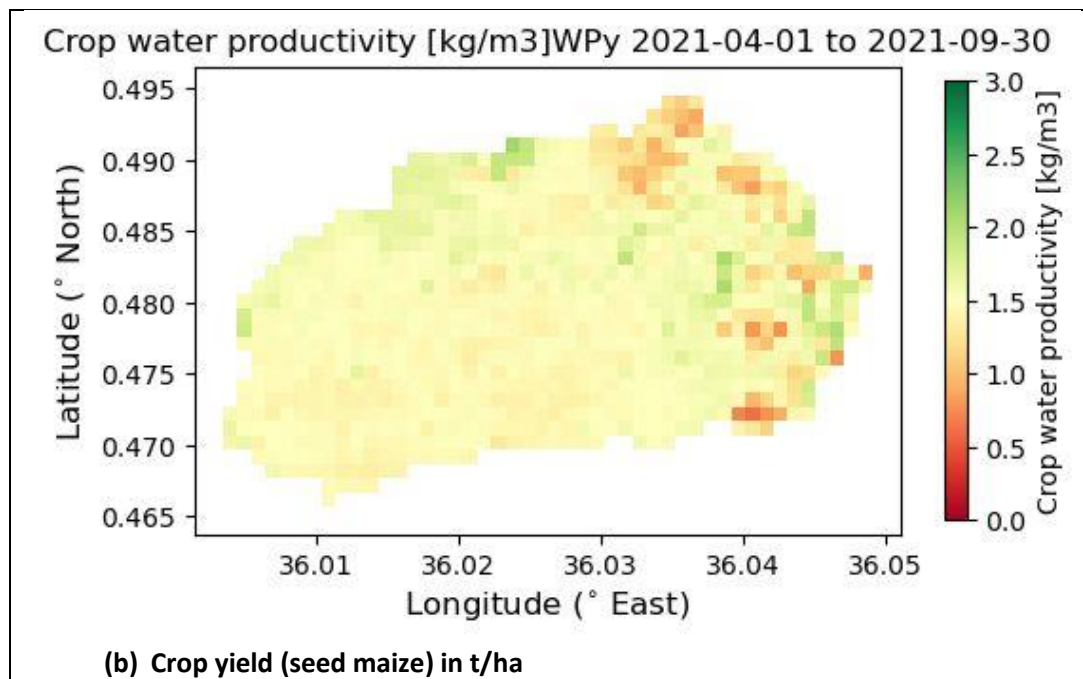
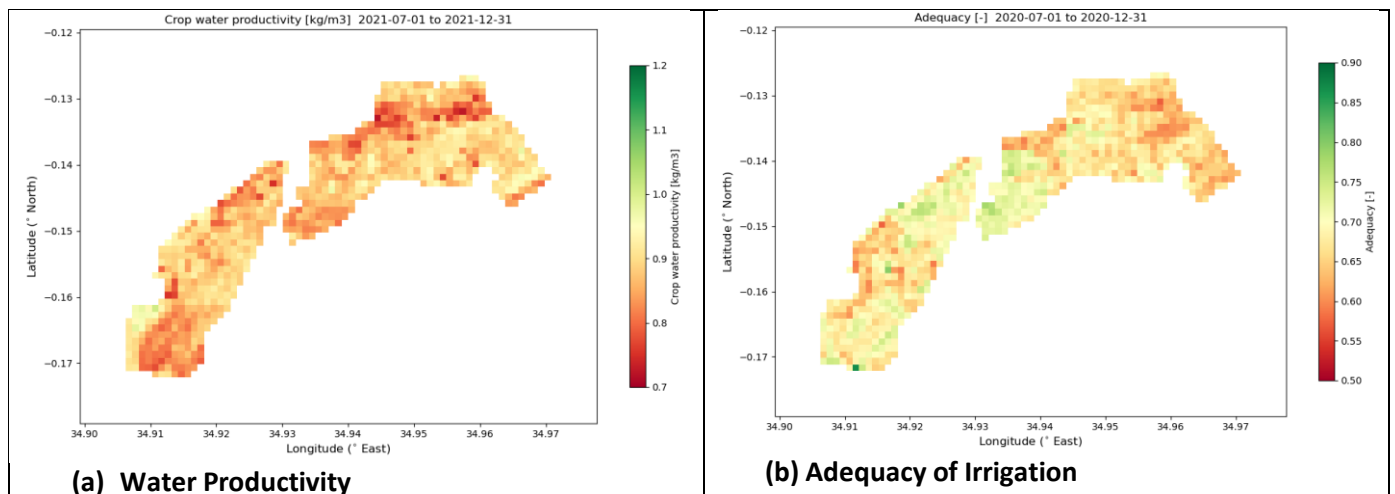


Figure 7: Simulated WAPOR outputs for maize at Perkerra for 2021

6) Results of simulated by WAPOR data for rice (IR variety) at Ahero

Ahero Irrigation Scheme is located on the edge of River Nyando in the Kano plains in Kisumu County. It is operated as a settlement scheme with the main crop being paddy rice. Ahero also enjoys oversight by the National Irrigation Authority (NIA) which manages the scheme. Water productivity is important at Ahero which uses basin irrigation. Thus, it was selected for WAPOR modelling. The results of WAPOR simulation (Figure 8) for paddy rice (IR variety) at Ahero Irrigation Scheme agree with values (4 t/ha/season) obtained from farmers and records by NIA.



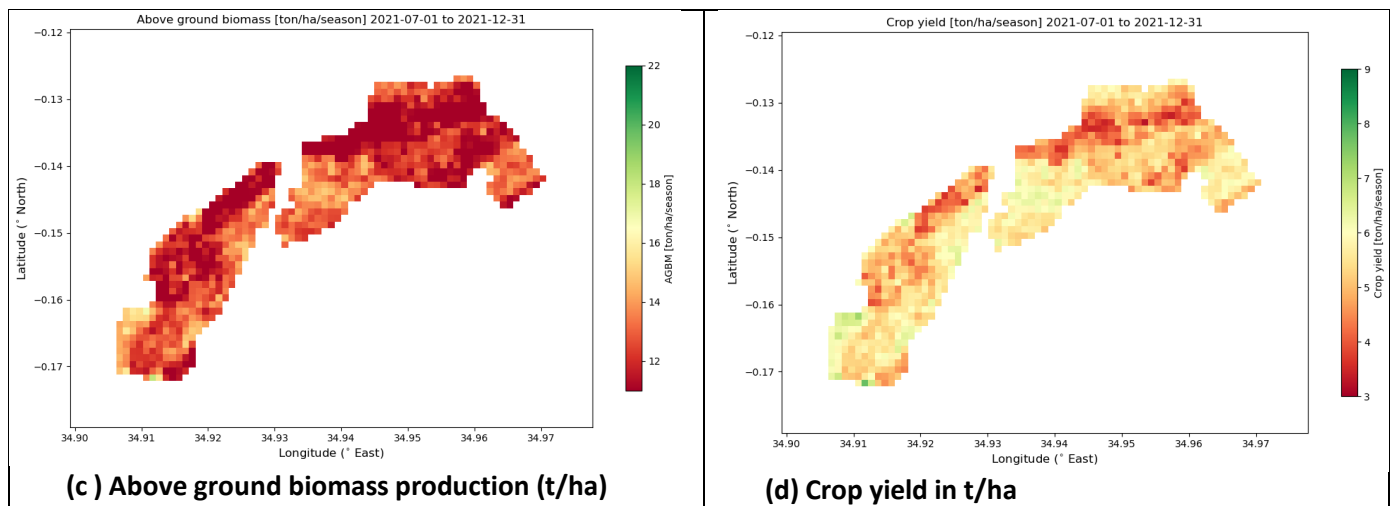
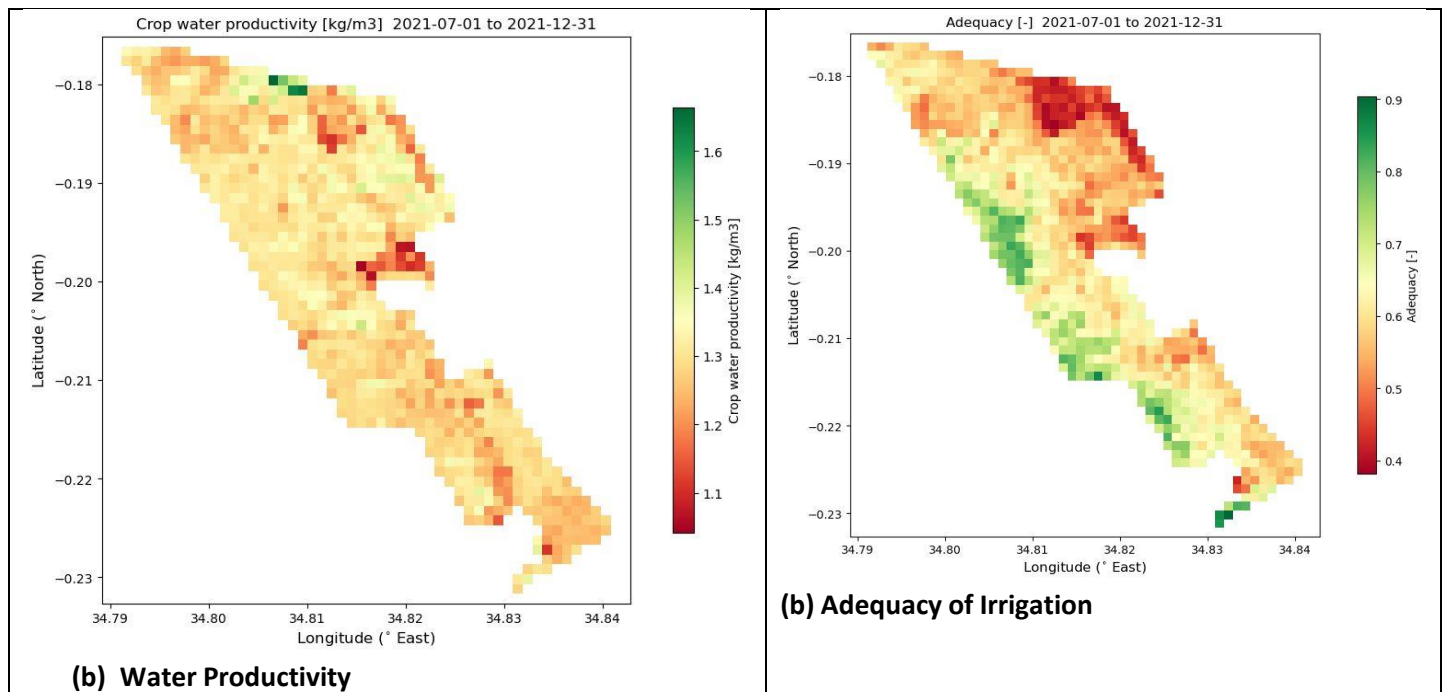


Figure 8: Simulated WAPOR outputs for rice at Ahero for 2021

7) Results of simulated by WAPOR data for rice (IR variety) at West Kano

West Kano Irrigation Scheme is located on the edge of Lake Victoria in the Kano plains in Kisumu County. It is operated as a settlement scheme with the main crop being paddy rice. West Kano is managed alongside Ahero as twin settlement schemes by the National Irrigation Authority (NIA), which manages the scheme. Water productivity is important at West Kano as it is a pumped scheme, where water is pumped in for irrigation, and later pumped out for drainage. Thus it was selected for WAPOR modelling. The results of WAPOR simulation (Figure 9) for paddy rice (IR variety) at West Kano agree with values (3.9 t/ha/season) obtained from farmers and records by NIA.



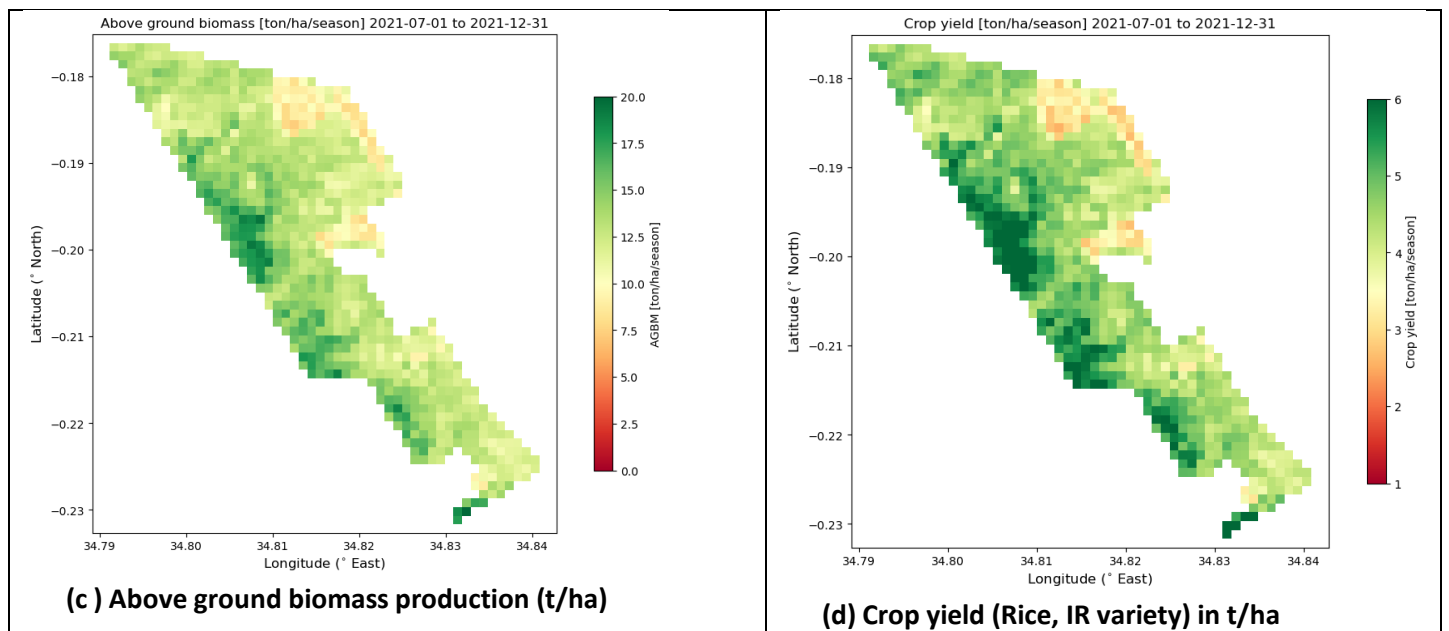


Figure 9: Simulated WAPOR outputs for rice at West Kano for 2021

4. EVENTS TO PROMOTE WAPOR AND DISSEMINATION OF INFORMATION

This component responds to Item 4 of AIAP's ToR, which has a requirement for "Event Reports". It stipulates that "The service centers are expected to have held at least three (3) events to promote WaPOR and associated services (ensuring country/stakeholder coverage)". AIAP actually held over six (6) events and thus, met and exceeded the ToR requirement. The six events were:

- i) Launch of WaterPIP Service Center at a national workshop hosted by AIAP;
- ii) Intuitional and capacity strengthening events;
- iii) Dissemination of WAPOR products to staff and farmers in Mwea Irrigation Scheme;
- iv) Dissemination of WAPOR products to staff and farmers in Kibirichia, Meru County;
- v) Dissemination of WAPOR products to farmers and Rea Vipingo staff in Kibwezi, Machakos County; and
- vi) Dissemination of WAPOR products to staff and farmers in Ramisi, Kwale County.

The types of WAPOR products disseminated at each event have been described above (Chapter3). Details of the promotional and stakeholder engagement to popularize WAPOR in are presented. In addition, the dissemination of information was done though a dedicated domain was inbuilt within AIAP's website (<https://aiap.or.ke/index.php/waterpip/>), for knowledge sharing.

4.1 Organizing and implementing promotional events

The WaterPIP service Center for Kenya was launched at a national workshop organized by AIAP on 10th December 2021 (Figure 10). This event, attended by 76 participants, and was used to promote WaterPIP as well as the concepts and best practices of improved water productivity.



Figure 10: WaterPIP launch at AIAP Webinar and partner institutions engaged

Other promotional events have included:

- i. Identifying users, beneficiaries and potential clients for the products and services of WaterPIP;
- ii. Stakeholder engagement through reaching out to potential clients and users of products and services from the Water Productivity Improvement Programme (WaterPIP);
- iii. Awareness creation through web content on the AIAP website, and participation in conferences and workshops;
- iv. Information and knowledge sharing with online content on the AIAP portal; and
- v. Promotional events by attending invited workshops (e.g. FAO's WAPOR-II launch).

4.2 Institutional and capacity strengthening activities

A number of institutional capacities were built to facilitate smooth implementation of the project and functionalization of the WaterPIP service center. These included:

- (i) Equipping the Service Center based at AIAP with necessary hardware and software to facilitate project implementation and knowledge dissemination;
- (ii) Training of staff and project team (conducted by Metameta and Eleaf) in February 2022. The training introduced remote sensing skills, use of WAPOR data, determining water productivity, scripting, advanced software, business case and other content;
- (iii) Exposure to reach a wider network/ audience for services and center promotion;
- (iv) Engaging with FAO as partners during the launch of WAPOR-2 and holding joint meetings;
- (v) Several meetings held virtually with Metameta and Eleaf to track project progress and sort out any issues as they arose; and
- (vi) Creating visibility of WAPOR by posting articles and content on AIAP's dedicated WaterPIP web domain (<https://aiap.or.ke/index.php/waterpip/>).

4.3 Dissemination of WAPOR products to stakeholders & events reports

The project Team carried out field visits to four field sites for which WAPOR data had been simulated, i.e. Mwea, Kibirichia, Kibwezi and Ramisi. The visits were used to ground truth WAPOR outputs as well as engage with stakeholders, considered to be possible clients. A total of 62 stakeholders were met (Annex 1). Prior preparation and mobilization had been done before each visit to gain audience for WAPOR products and meet persons at decision making levels as well as local farmers. The services for each site visited were tailored to suit the audience and relevance of the project regarded as the main objective for the project. The following are the event reports of the field visits undertaken in November 2022:

4.3.1 Promotional events implemented at Mwea Irrigation Scheme

The first meeting with the Manager and senior staff of Mwea Irrigation Scheme was held in January, 2022 (Figure 1a), at which it was agreed that WAPOR simulation would be tested in Mwea as a precursor to future collaboration. Two other visits were made by the project team for ground truthing. The final event combined ground truthing exercise for finished WAPOR products (maps, data), holding meetings with staff at MIAD and CadPERP and participation in a farmers' field day at Tebere Block within Mwea (Figure 11). Through these events, the project team shared the findings of WAPOR simulation for Mwea and gathered feedback from

stakeholders, who included government officers, private sector agro-input dealers and farmers. MIAD manager and CaDPERP manager accompanied by their respective staff participated. Others included KALRO staff, local chief and village elders, provisional administrator in charge, county executive for water and irrigation, county director for Agriculture and NIA representative for Rice Promotion Program, JICA senior representative from the Japan corporate office and private investors mainly promoting their products which were largely pesticides, herbicides and fertilizers for the farmers. AIAP project team interacted with the farmers and other stakeholders, sharing information and WAPOR outputs i.e. maps showing water productivity and crop yields.



Figure 11: Stakeholder engagement in offices and at a field day in Mwea Irrigation Scheme

4.3.2 Visit to Meru County offices and Kibirichia farmers

Kibirichia sub-county is a major potato producing area, cultivated mostly by small-scale farmers. Both rainfed and irrigated agriculture is practiced including other crops such as cabbage and peas. A field visit event started with meetings with Ministry of Agriculture staff at Meru County offices (Figure 12). It was reported that due severe drought experienced across the country over the last two years, Kibirichia was also affected and its potato yields had dropped drastically. The county office was willing to collaborate with AIAP on using WAPOR data to inform crop insurance services for different crops. This could be done using harvest index derived from WAPOR data as compared to the conventional way where maize farmers are insured based on area under crop, but performance of that crop remained unknown during the growing period till at harvest.

Thereafter farmers were visited in Mathongo area within Kibirichia ward. The farmer reported that he harvested about 10 t/ha from the block the season that ended December 2021 but currently had wheat. The WAPOR yield prediction gave an estimated value of 8.2tons/ha. It was apparent that WAPOR simulated data closely matched that reported by the farmers.

The second farmer visited had a relatively large farm. He also practiced mixed crop farming using modernized machinery. He practiced irrigation on his farm using pumps and sprinkler irrigation system, the water used was harvested from rooftops into an underground dug water pan of 2000m³ capacity. He also had a bio digester within the farm where all his manure would pass through before being released to the farms and the biogas safely directed to kitchen for cooking.



Figure 12: Stakeholder engagement at Meru Agriculture office and visiting a potato farmer in Kibirichia

4.3.3 Visit to Chumani and Rea Vipingo sisal estate in Kibwezi

This event in Kibwezi sub-county was in two parts; First a field visit was made to meet small scale farmers who were preparing a sisal nursery at Chumani. The farmers are organized in a CBO (Community based organization) which has various projects, one of which is to engage in sisal farming as a cash crop. After participating in the sisal nursery planting, the AIAP team held a meeting with the farmers (Figure 13) and their leaders explaining about the role WAPOR data could do to promote sisal as a climate-smart crop suited to the area. The farmers suggested that they would require water harvesting for irrigating the sisal nursery so that the seedlings could establish faster. Sisal had a ready market both at the nearby Rea Vipingo estate, but the group sold their fiber to a buyer who came from Nairobi because he paid a higher price. WAPOR data would come in handy for policy advocacy to support the farmers' efforts.

The second part was a visit to Rhea Vipingo Sisal estates and a meeting with the company staff. The Company would like to promote sisal cultivation among the small holders as demand for fiber was much higher than the company could meet. It was also reported that crop yield stood at 15 tons/ha in total. The WAPOR crop yield estimate for the estate was between 15 – 20 t/ha showing close correlation. The company staff were interested in the outputs of WAPOR data and were left with some of the maps. There is scope for promoting this abandoned yet demanded

crop through policy advocacy and awareness creation, whereby WAPOR data comes in handy to proof that water productivity of sisal as makes good economic sense.



Figure 13: Field visit to Chumani CBO and Rea Vipingo sisal estates in Kibwezi, Makueni County

4.3.4 Meeting at Msabweni sub-county office and visiting Ramisi sugar plantation

This event had two parts; the first part involved a meeting with Ministry of Agriculture staff at Msabweni Sub-county offices (Figure 14), followed by a field visit to KISCOL (Kwale International Sugar Company Limited) sugar plantations in Ramisi. The KISCOL Plantations are the largest irrigated sugar in the country, albeit they also grown rainfed crop.. The project team showed the staff at the office WAPOR and products for the areas, and they were quite interested with data on water productivity and sugarcane yield. The KISCOL staff talked with the project team via telephone. They reported that KISCOL records sugarcane yields about 150 t/ha per year for the irrigated crop and about 70 – 80 t/ha per year for the rainfed crop. The WAPOR crop yield estimate for the sugarcane estate was of 120 t/ha which mirrors values recorded for irrigated sugarcane. There is scope to make use of WAPOR data especially to promote out-grower sugar production through policy advocacy with the Kwale County Government, outgrowers and other stakeholders.



Figure 14: Meeting staff at Msawbweni Sub-county offices and sugar plantation at Ramisi, Kwale County

4.4: Service Center Interactive knowledge sharing through ICT

This component covers the activities implemented with AIAP offices to promote WAPOR and provide knowledge as the WaterPIP Service Center for Kenya. It started (February 2022) with equipping the Service Center with requisite hardware and software, thus providing ICT capabilities for networking and knowledge sharing. Thereafter the WaterPIP service center disseminated information and WAPOR products through various ways, which include; online WaterPIP portal, interactive offline dashboard and GitHub repository, done as follows:

4.4.1 WaterPIP portal hosted by AIAP

The WaterPIP portal is hosted on AIAP website (<https://aiap.or.ke/index.php/waterpip/>) and set as a menu item, readily accessible to visitor accessing AIAP website. The portal contains articles, reports and sample map data on WAPOR project, which is open access for public to view or download. The portal also presents updated WaterPIP news for public consumption. The portal acts as an advertisement platform for the WAPOR products and for the service center.

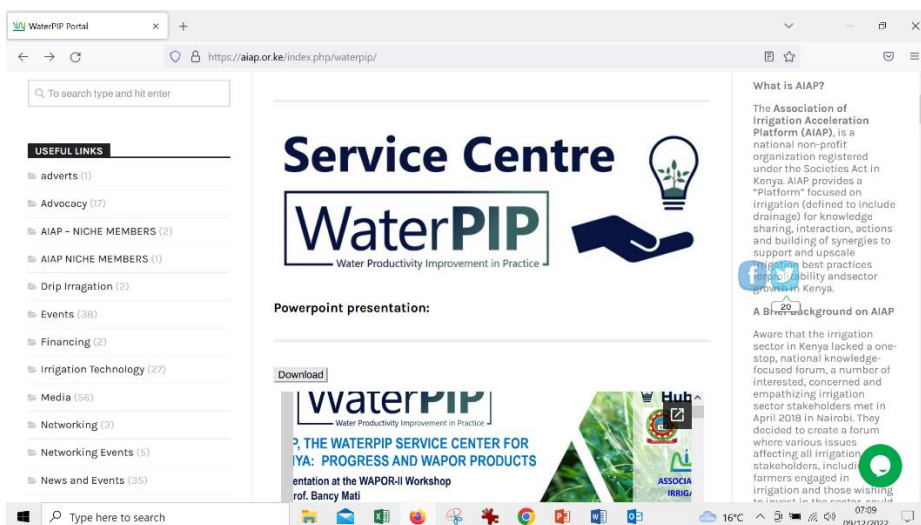


Figure 15: Screenshot of the interactive WaterPIP Dashboard

AIAP also created an offline portal to process and store various map files for the selected regions. This dashboard is connected with various python machine learning algorithm scripts from WAPORACT library to easily generate WAPOR maps for various selected locations. The portal also stores the map data for future reference. The dashboard calculates water productivity, biomass and crop yield for selected areas and outputs the result to the end user.

4.4.2 GitHub Repository

The repository contains all the codes for generating and presenting processed WAPOR map data. The GitHub repo (Figure 16) serves as codebase reference for the Water PIP python scripts. The repo also aids in version control of the newly created Water PIP tools for Kenyan service center.

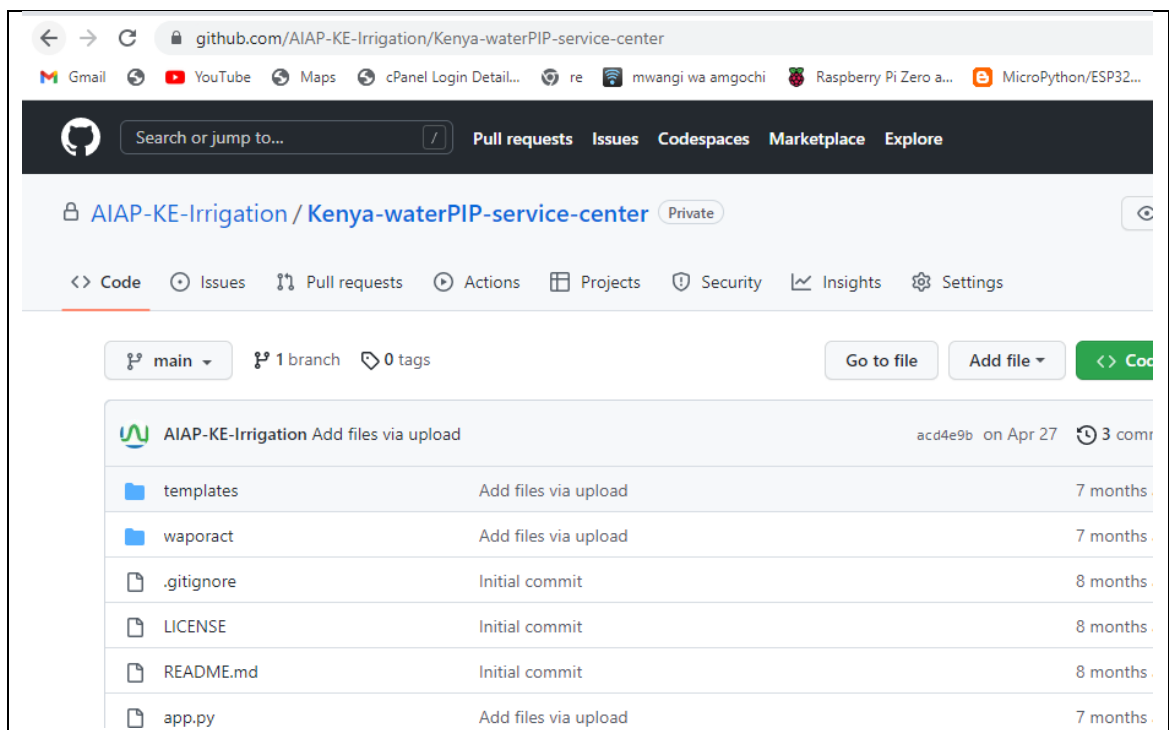


Figure 16: Github Page for Kenyan service center for WAPOR

4.4.3 Machine learning scripts.

The scripts are written in Python and automated to retrieve and process WAPOR dataset for various selected locations within Kenya and display the results in terms of GIS map and text data. The python scripts also act as API (Application Programming Interface) on the offline dashboard.

5. CONCLUSIONS AND LESSONS LEARNT

This Project set out to establish a distinct and interrelated Service Centre (WaterPIP) in Kenya, focusing on the agriculture-water-environment nexus, in a bid to downscale improved water productivity thinking and practice in Kenya. To assure targeted and user-friendly information, AIAP was charged with responsibility to contribute to the customization of WaPOR (Water Productivity through Open access of Remotely sensed derived data) tools, such as remote sensing products, scripts, protocols and content developed by WaterPIP project to local contexts. This component has been successfully implemented and the Service Center is up and operational.

The methodologies and activities to deliver WAPOR products were developed cognizant of the fact that WAPOR has lowspatial resolution of 100 m, and thus the need to select areas having extensive coverage of a monocrop for accuracy of results. Using logical criteria and taking into account the possibility of engaging stakeholder to become clients for WAPOR data, some seven field sites in Kenya were selected for which WAPOR simulation was successfully done. The sites are: Mwea, Kibirichia, Kibwezi, Ramisi, Perkerra, Ahero and West Kano. The outputs in terms of downscaled data produced a total of 497 individual output maps for all the sites. These maps capture quantified data on five variables, viz: water productivity, biomass production, crop yield prediction, adequacy (relative evapotranspiration), and beneficial fraction of irrigation water. The map data were further verified through field visits to Mwea, Kibirichia, Kibwezi and Ramisi. Generally, the values obtained from WAPOR simulation for all the crops and field sites closely matched observed yields when compared to farmer level data. This indicates that WAPOR can be used to predict crop performance and yields in Kenya, provided a monocrop is the target crop.

The main Challenges faced included: Low Resolution of WAPOR data (100 m) which was too coarse for simulation of small-scale croplands. This challenge was overcome by selecting *areas of large scale irrigation and those growing a monocrop e.g. rice, sugar and sisal plantations*. It was noted that applying WAPOR to mixed crop types and planting dates increases noise in the output data. Also, it was not possible to predict yield of fruit trees (e.g. citrus, mango, bananas) as had originally been conceived. However, it was found that WAPOR could be used as a policy tool for rainfed crop, e.g. sisal, where the benefits were easily demonstrated using drought years, being a climate-smart crop with multiple benefits, as compared to food crops.

Another challenge was how to convert stakeholders interested in water productivity, e.g. National Irrigation Authority, into “customers” for WAPOR data, due to technicalities of government procurement procedures and protocols. Moreover, private sector irrigation schemes are too advanced in how they track WP and thus are unlikely to be interested in WAPOR outputs. It was thus concluded that public sector institutions hold possibility for becoming WAPOR clients (not necessarily customers) as they do not assess WP in most irrigated areas in Kenya, and demand for improved WUE is growing driven by water scarcity and climate change challenges.

Towards promoting use of WAPOR data, there is evidence that AIAP provided more than 5 services as the WaterPIP service Center for Kenya. Furthermore, AIAP held over six (6) events to promote WAPOR (ToR required at least 3 events), which included workshops, training events and

meetings with stakeholders. A total of 62 stakeholders were met. In addition, capacity was built within AIAP to handle remote sensing data and processing to provide products that have local applicability. There is still need to grow the Center to handle higher more RS data and meet user demand as part of its service delivery. Meanwhile, a dedicated WaterPIP web domain (<https://aiap.or.ke/index.php/waterpip/>) was created in AIAP's website for knowledge sharing, and also to publicize WAPOR widely.

Next actions include the need to create a demand-driven value chain for WP data. This will be coupled with identifying user demand for WP data for decision making at farm level and modalities for cascading to Policy level. Also to take WAPOR to the next level through engagement with policy makers for its wider adoption in Kenya. AIAP would like to build a community of practice for upscaling WP in irrigation in Kenya through its network which covers the whole country. If possible, even reach out to neighboring countries, e.g. Uganda to start a WaterPIP Service Center and upscale WP through outreach

