




EO Africa // ARIES

D02 – African Early Adopters characterisation and benefit analysis report Version 1.0, February 2023

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submitted by

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ESA STUDY CONTRACT REPORT

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<p>ABSTRACT:</p> <p>This document characterizes the African users and describes their requirements Combined with the scope of the project, it translates these into product requirements as well as system and operational requirements.</p> <p>Version 1.0</p> <p>Status: 03. February 2023</p> <p>The work described in this report was done under ESA Contract. Responsibility for the contents resides in the author or organisation that prepared it.</p> <p>Names of authors: Laurent Tits (Vito), Jeroen Degerickx (Vito), Veronika Otto (Vista), Silke Migdall (Vista)</p>		
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List of Acronyms

ACF	Action contre la faim (Action against hunger)
AGRHYMET	Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle
AKTC	Zambian Agricultural Knowledge and Training Centre, LTD
AU	African Union
CILSS	Comité permanent inter-État de lutte contre la sécheresse au Sahel (Permanent interstate Committee for Drought Control in the Sahel)
CSE	Centre de Suivi Ecologique
ECOSTRESS	Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station
ECOWAS	Economic Community of West African States
EO	Earth Observation
ESA	European Space Agency
FS TEP	Food Security Thematic Exploitation Platform
LSTM	Copernicus Land Surface Temperature Monitoring
NGO	Non-governmental Organisation
PRISMA	PRecursore IperSpettrale della Missione Applicativa
R&D	Research & Development
RCMRD	Regional Centre for Mapping of Resources for Development
SWIR	Short Wave Infrared
TEP	Thematic Exploitation Platform
UNECA	United Nations Economic Commission for Africa

1 Executive summary

This document summarizes for the ESA ARIES project the requirements as collected from users, on both the products, the system, and operational aspects, as collected through a series of consultations with the project's Users from Africa. Four organizations were considered in this exercise, namely Agrhymet, RCMRD, ACF and AKTC. Through a series of interviews, the needs of these users were identified, and translated into concrete requirements that will steer the research and developments in the ARIES project.

The four users represent a wide range on how EO is used within these organizations. ACF and AKTC are typically users that provide very concrete services to a wide range of users, including farmers and agropastoralists. Operational EO data products are embedded in a number of their services, and they are keen to improve these services with better EO data products. Agrhymet and RCMRD, on the other hand, have extensive EO data processing capabilities, and have a long track record on working with and developing new EO data processing workflows. Their interest is both on improved data products, as the availability of better input EO data, that could be used in a wide array of applications.

A key component of ARIES is to evaluate how hyperspectral (PRISMA/EnMAP) and higher-resolution thermal data (ECOSTRESS) can contribute to drought-related impact monitoring on vegetation. Performant drought-monitoring tools are still in high demand, with many known bottlenecks in the current operation missions. For many of the users, the capabilities of these data are quite unknown, but their potential contribution is of great interest. In general, there is a high interest and response level from the different users.

A key requirement that was formulated by all users is the impact of drought and water stress on crop and forage productivity. The limited availability of good indicators that can quantify drought severity or drought onset is highlighted by all users, and should be the main focus point of the project. The applications hereof range from grassland productivity in the rangeland systems, to yield estimations in irrigated and rainfed croplands.

There will thus be a dual focus in the R&D activities to meet the user needs:

- Improved EO input data: combine data from multiple missions to provide high-quality thermal data with improved spatial and temporal resolutions.

- Performant drought indicators: provide indicators that can be used in the current operational monitoring tools, to (i) determine the onset of drought, to help steer the water management in irrigated croplands, and (ii) determine the impact of drought on the productivity of croplands and rangelands provide information of the yield/available feed at the end of the growing season.

2 Purpose and scope

The focus of this User Requirements Consolidation activity was on engaging with and starting the integration of users from the start of the project, understanding their needs, expectations, technical and human resource capabilities, and defining their requirements for the ARIES products and tools. This information was collected through a series of engagement meetings with each user and consolidated into the priority requirements and preferences that will be used to guide the research questions and developments. It is important to note that this is a critical, yet initial step of the project, and we expect that as the project progresses and users become gradually more engaged there will be modifications and more details added to these requirements.

3 The African users

There are four users included in this User Requirements Consolidation activity. The users were selected during the proposal phase based on their link with the proposed thematic domain (agricultural water resources management, drought monitoring and food security) and their specific location on the African continent, thereby maximizing the variability in environmental conditions and agricultural practices covered by the project.

In the following sections, these four users are briefly introduced. In Section 4, we look into their specific User Requirements related to high resolution drought indicators, the thematic focus of the ARIES project.

3.1 ACF

Created in 1979, the Non-Governmental Organization (NGO) – Action Against Hunger – is fighting against hunger in the world. Its mission is to save lives eradicating hunger through the prevention, detection, and treatment of malnutrition, in particular during and after emergency situations caused by conflicts and natural disasters. Today, Action Against Hunger is a major player in the fight against hunger in the world. Structured on an international network, the organization provides a coordinated response in nearly 50 countries. The priority is to have effective actions in the fields and testify about vulnerable population.

The main contact was Erwann Fillol (erfillol@wa.acfspain.org)

3.2 Agrhymet

The AGRHYMET regional Centre was created in 1974, as a specialized institution of the Permanent interstate Committee for Drought Control in the Sahel (CILSS). It has 13 member states and is covering the Economic Community of West African States (ECOWAS) region. The primary objectives for AGRHYMET are to contribute to achieving food security and increased agricultural production in the ECOWAS region and to improve the natural resources management in the Sahel, by providing training and relevant information to all stakeholders and partners in agro-ecology.

The main contacts were:

- Dr. Zakari S. Abdourahamane (abdourahamane.zakari@cilss.int)
- Dr. Issa Garba (issa.garba@cilss.int)

3.3 RCMRD

RCMRD, the regional centre for mapping of resources for development was established in 1975 under the auspices of the United Nations Economic Commission for Africa (UNECA) and African Union (AU). Their mission is to promote sustainable development through generation, application and dissemination of geo-information in the member states and beyond. Their member states span Eastern and Southern African regions. One of the major activities of their remote sensing unit is carrying out research and consultancy services on the application and use of photogrammetric technologies in natural resources mapping, infrastructure and designing, urban mapping, precision agriculture and irrigation development.

The main contacts were:

- Josphat Makanga (jmakanga@rcmr.org)
- Pauline Ogola (pogola@rcmr.org)
- Waswa Rose Malot (rwaswa@rcmr.org)

3.4 AKTC

The Zambian Agricultural Knowledge and Training Centre, LTD (AKTC) was funded as spin-off from a project within the Bilateral Cooperation Program of the Federal Ministry of Food and Agriculture in Germany and the Zambian Ministry of Agriculture in 2015. The AKTC supports the building of a resource-saving agriculture and food industry through its diverse training courses for farmers, service providers and multipliers as well as agricultural advisors, lecturers and students. The AKTC conducts field demonstrations and research on both irrigated and rainfed agricultural land at the Golden Valley Agricultural Research Trust's (GART) Chaloshi farm to promote sustainable agricultural management practices.

The main contact was Helmut Anschutz (Helmut.Anschuetz@afci.de)

4 User Requirements

4.1 Initial requirements

The scope of the project, and the framework within which the requirements of the users needed to be mapped, was delimited by the initial requirements set forth by ESA in the tender documents, as well as the description of the planned work in the project. Concretely, this means that product specifications are strongly determined by the used EO input data, with the thermal ECOSTRESS and the hyperspectral PRISMA and ENMAP data at the core of the research objectives. The major characteristics of these sensors are shortly listed in Table 1.

Table 1: Data characteristics for the three main sensors included in ARIES.

Sensor	Data type	Number of bands	Spectral window	Temporal resolution	Spatial resolution
ECOSTRESS	Thermal	6	8-14 μm	3-5 days	70m

PRISMA	Hyperspectral	241	400- 2500 nm	7 days	30m
ENMAP	Hyperspectral	228	420 nm - 2450 nm	4 days	30m

In addition, the initial overview of the foreseen products (Table 2) was used to steer the interview, to enable a targeted inquiry of the needs in function of the capabilities of the consortium.

Table 2: Initial proposal of products to be developed within ARIES.

Product	Description	EO inputs	Spatial resolution
Ecosystem water stress	An indicator signifying the amount of water stress received by the landscape.	ECOSTRESS, meteo	70m
Crop water stress	High resolution indicator on water stress experienced by crops.	Sentinel-3 LST, Sentinel-2 optical bands, meteo, DEM	20m
Drought susceptible area	Rapid change index (RCI) based on STR	Sentinel-2 SWIR bands	10m
Plant leaf water content	Modelled using radiative transfer models	PRISMA, ENMAP	30m
Green plant leaf area	Modelled using radiative transfer models	PRISMA, ENMAP	30m
Canopy water content	Combination of leaf water content and leaf area products	PRISMA, ENMAP	30m

4.2 User characterization

It is important to note that the different users in this study have a diverse background, which influences their requirements for an R&D project like ARIES. The scope of the project is mainly focused on demonstrating potential uses of these promising new data sources, rather than developing innovative operational products. For users such as ACF and AKTC, the main interest is in adopting novel EO products that can directly be applied in their daily operations. Both are already using EO data in a number of their applications, such as the Copernicus DMP product in the pastoral information system of ACF and Vista's VariableRain product in AKTC's irrigation management. They are well aware of the limitations of the current operational EO products, and have clear requirements for novel EO products in order to improve their services.

Agrymet and RCMRD, on the other hand, are much more R&D – oriented. They are involved in a broad range of EO-related projects, of which many could benefit from the

improved EO-data products foreseen in ARIES. While they are working on specific applications, they could also benefit from a number of improved EO inputs, as they have the capacity to integrate these inputs in other workflows.

4.1 Study areas and user specific needs

In the following sections we present the specific sites which were proposed by each African user as pilot test sites during product development within the ARIES project. For each of the sites, we provide more information regarding the specific thematic data needs.

4.1.1 ACF

Given the wide range of applications ACF is active in, two sites were proposed, each with a distinct objective and hence specific data needs.

The first site consists of three pastoral areas in Senegal (Figure 1), more specifically located in the Louga and Tambacounda districts. Here ACF is in close collaboration with the Centre de Suivi Ecologique (CSE). The main interest is in **standing biomass** (during the dry and rainy season), and any indicator that can help in identifying issues with production, such a **drought**. An additional request was made for the presence and amount of **open surface water** for cattle to drink.

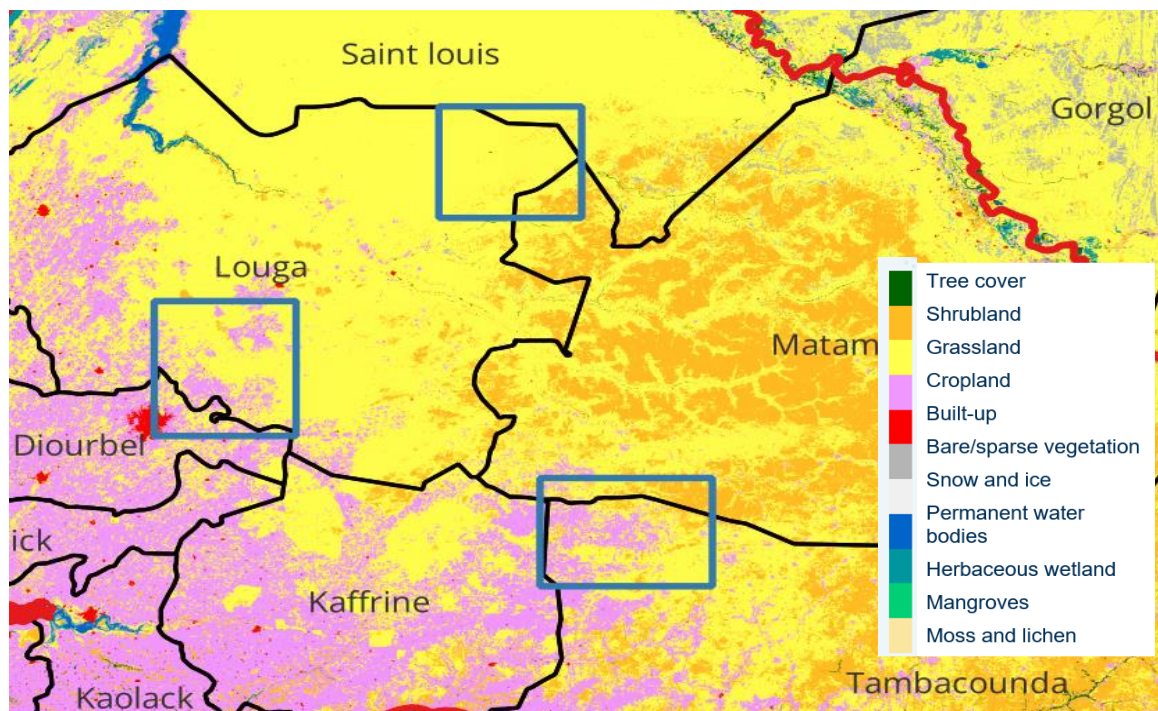


Figure 1: Location of three test sites (marked in blue) in Senegal mainly consisting of pastoral areas, as proposed by ACF. ESA WorldCover 2021 map is used as background layer.

The second site proposed by ACF is located in Mali, more specifically in the Tombouctou district (Figure 2). Within this region, ACF is particularly monitoring the irrigated cropland area along the Niger river. The main interest here is in the early detection of **crop water stress** to manage the irrigation practices, and monitor the **biomass production** throughout the season. If possible, end-of-season **yield estimations** would be an added value as well.

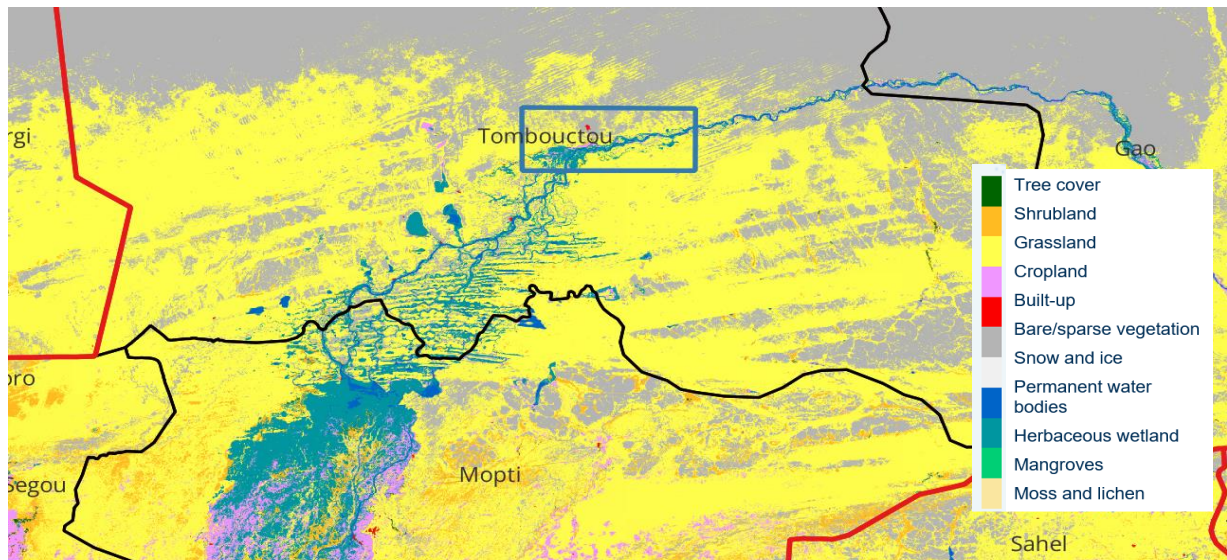


Figure 2: Location of test site in Mali (marked in blue) containing irrigated cropland, proposed by ACF. ESA WorldCover 2021 map is used as background layer.

4.1.2 Agrhymet

In general, Agrhymet is tasked with monitoring the impacts of droughts on crop and grass biomass production and forecasting the occurrence of droughts throughout the Sahel region. One particular region which is often the main focus of their research projects, is the rural district of Diantchandou in Tillaberi, Niger, an area of around 1000 km² located closely to the capital Niamey (Figure 3). This area mainly consists of pastoral areas and rainfed agriculture, with only limited occurrence of irrigated cropland. Prior to the start of the rainy season, around April-May, Agrhymet publishes **crop production** forecasts, which are, throughout the growing season (June – October) updated at a 10-daily and/or monthly interval based on current crop conditions and the latest weather forecasts. The update frequency of the forecasts is often constrained by the availability of valid satellite observations. At the end of the growing season, final production and yield estimates are published. **Crop conditions** and biomass productivity are typically assessed using a combination of low-resolution satellite data (MODIS, SPOT, Proba-V) and in-situ surveys performed by local experts.

During the dry season, their main interests concern the availability of **dry biomass** and the extent of **surface water bodies**, as both factors determine the most optimal grazing routes.

In terms of required **spatial resolution**, Agrhytmet experts stressed that there is currently a lack of high resolution (< 30 m) products and indicators to assess crop conditions/biomass productivity on individual agricultural fields. Some experimental analyses have been done in the framework of other research projects using Sentinel-2 and/or Landsat optical data, however mainly focussing on crop type detection and land cover mapping. Specifically for surface water bodies, 30m resolution maps were deemed not detailed enough, as the extent of these temporary water bodies is limited and highly dynamic. With regards to **temporal frequency**, weekly to 10-daily updates on crop growth conditions were deemed necessary in order to match the reporting frequency of Agrhytmet. Ideally, this would be based on daily estimates of crop water stress, as droughts are typically defined as prolonged conditions of water stress exceeding 7 days.

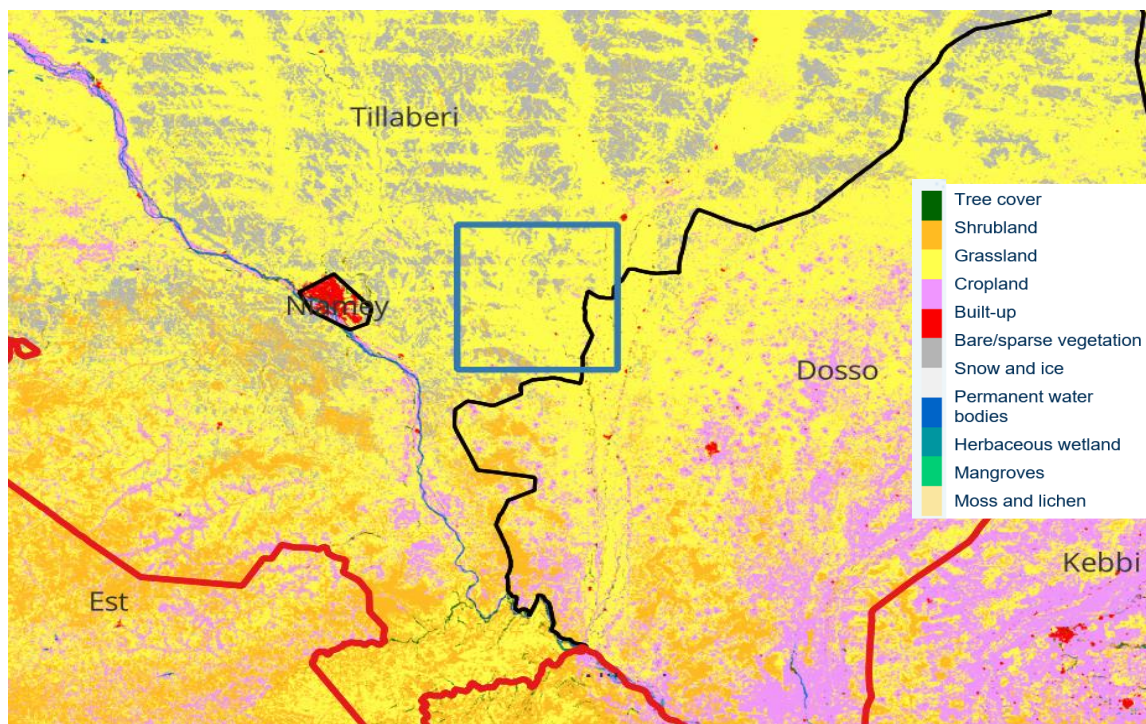


Figure 3: Location of Diantchandou rural district in Niger (marked in blue), proposed test site by Agrhytmet. ESA WorldCover 2021 map is used as background layer.

Given their specific data needs, all products initially proposed to be developed within the ARIES project (Table 2) were deemed relevant and interesting from their point of view. The leaf area product is expected to be most relevant to be linked to biomass

productivity in the pastoral areas, whereas the crop water stress estimates will be most beneficial to finetune biomass productivity assessments and predictions on rainfed agricultural land. Particular interest was shown to the use of thermal satellite data to assess water stress and drought conditions, as no prior experience has been gained within Agryhmet on the use of this data type.

4.1.3 RCMRD

RCMRD has many ongoing projects in which they provide spatially-explicit information to agricultural stakeholders based on Earth Observation data. Their main interest within ARIES rather lies in the **innovative data fusion methods** which will be employed to translate hyperspectral/thermal data to information relevant for the farmer, rather than in the specific data products themselves. RCMRD operates in Kenya but has not provided a specific area of interest to be considered. They are willing to validate the findings of ARIES on a number of their ongoing projects.

4.1.4 AKTC

The region of interest provided by AKTC, located within the Central region in Zambia, mainly contains irrigated and non-irrigated agricultural land (Figure 4). Within this region, a wide variety of farming practices are used, particularly with regards to soil cultivation. A distinction can be made between conventional farming (burn and slice) and regenerative agriculture (the use of cover crops and direct seeding). An overview of management practices applied within the AKTC test sites is shown in Figure 5.

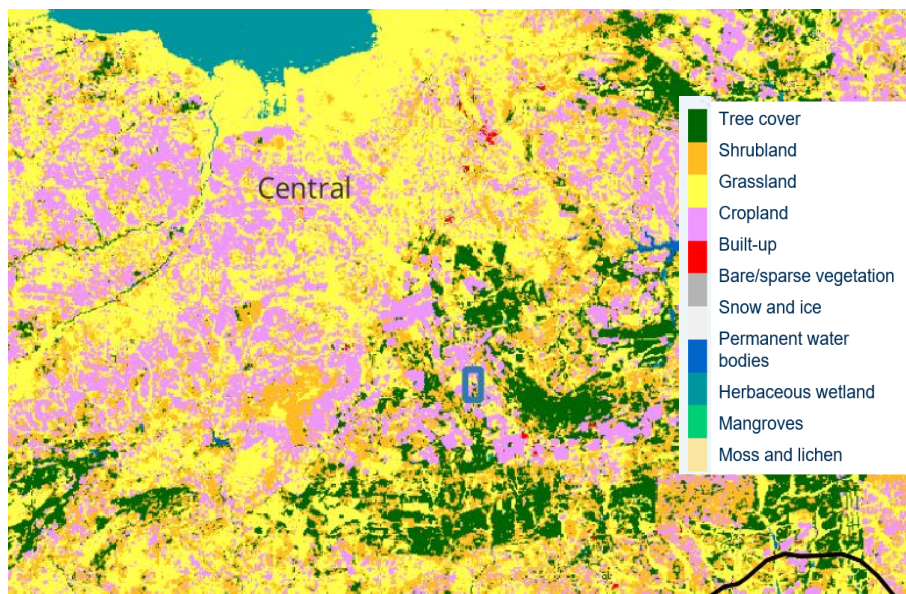


Figure 4: Location of AKTC agricultural test sites (marked in blue) within the Central district of Zambia. ESA WorldCover 2021 map is used as background layer.

CAFM PROJECT FIELD LAYOUT - 27ha

2022-2023 SEASON

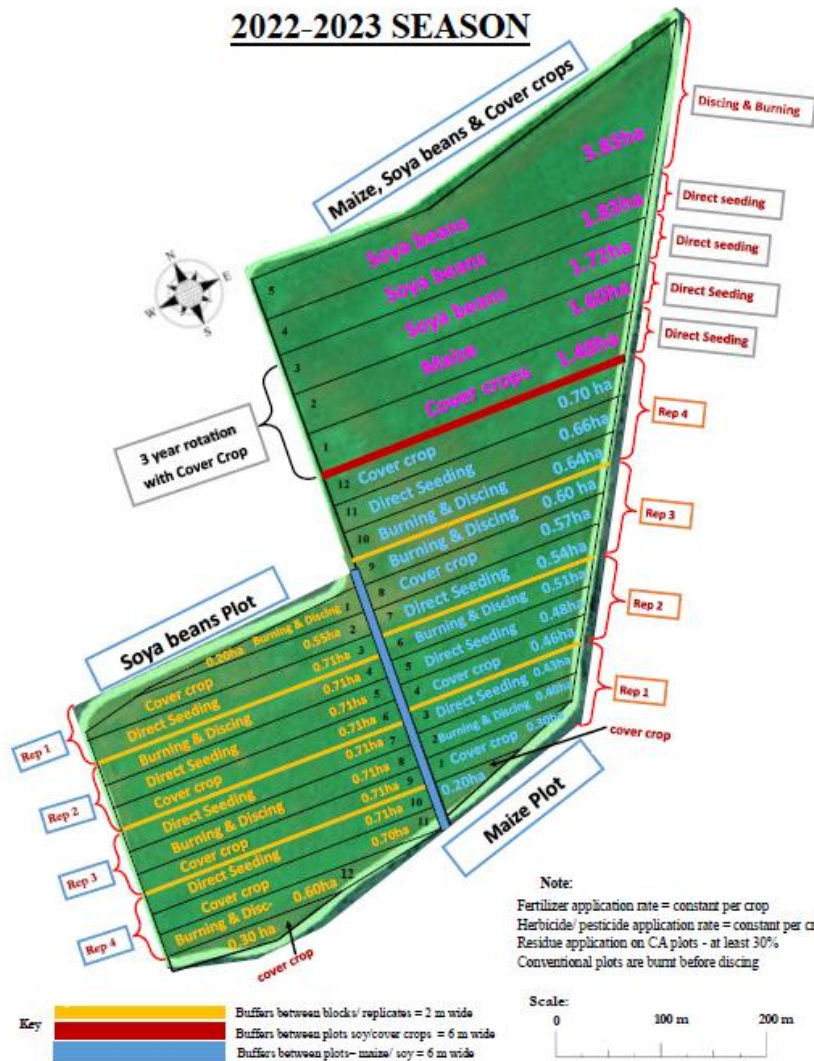


Figure 5: Overview of cultivation practices applied at the AKTC test sites in Zambia.

The main goal of AKTC at these agricultural test sites is to demonstrate the added values and benefits of regenerative farming compared to traditional farming practices. Estimates on **leaf area index**, **biomass**, occurrence of **plant water stress**, **crop nutrition status** and the occurrence of **pests and diseases** have all been highlighted as relevant information. The required timing of these information needs varies depending on the objective. For day-to-day farm management, current state information is most relevant. Especially for irrigated lands, it is relevant to know when crop water stress is starting, so that irrigation can be applied in a timely manner. For dry lands this kind of water stress risk warning is less relevant, because there are no

counter measures available. However, in case **yields** would be affected it is still deemed useful to know in advance. Retrospective information (typically at the end of the growing season) is deemed to be most relevant for the estimation of effectiveness of regenerative agriculture. In addition, the possibility to detect **water logging** was also mentioned so that drainage systems can be put in or repaired, if the logging stems from a broken system.

Field-by-field information is most practical for day-to-day management. Pixel based information is preferred to get an overview and for specific products (e.g. water logging). Data should best be shared in the form of actual maps (e.g. PDF), as this is most practical for farm management. Data for use in GIS (e.g. TIFF or Shape) are, if at all, only relevant for use by doctoral students.

4.2 Consolidated user requirements

From the interviews with the different users, one overall and common use case was highlighted, being the impact of drought/water stress on crop and forage productivity. Biomass and productivity measures in general are an important component in many of the operational and/or developed monitoring tools of the users, and a key bottleneck is to properly account for the effect of drought, due to the limited availability of good indicators that can quantify drought severity. The applications range from grassland productivity in the rangeland systems, to yield estimations in irrigated and rainfed croplands.

This can be considered the overarching use case, that will be further detailed for specific users. For example, a crucial element will be the detection of when the crop experiences water stress, and for how long. In irrigated areas, this information would be used to steer irrigation practices, and early in-season mapping is important. However, for rangelands this information will mainly be used to map areas with reduced grassland biomass production, as it will impact feed availability during the dry season for the cattle.

As a consequence, while the thematic requirements are quite similar, the technical requirements that drive the research foreseen in ARIES is fundamentally different for both use cases of cropland and rangelands monitoring. For the **cropland monitoring**, there is a need for NRT-monitoring capabilities, at a spatial resolution that is as fine as technically possible, to enable the monitoring at the (sub-) parcel level. This means that from a technical side, a large emphasis will need to be put on **upscaling the thermal information**, and **increasing the revisit time as** much as possible.

For the **rangeland monitoring**, the focus is more on scalable solutions that can be deployed over large areas in a time- and cost-efficient manner. The spatial resolution of 60m is not a bottleneck for this application, and the revisit times are not considered as a current bottleneck. The focus here will thus be mainly on the thematic requirements.

5 Product specifications

From the thematic user requirements, combined with the proposed product list in Table 2, the main focus will thus be on identifying which hyperspectral and thermal data products can provide the needed information on drought onset, drought severity, and the impact of drought on productivity and yield.

A distinction will need to be made between the cropland and rangeland use cases. For the rangelands, these developments can be done on the original thermal and hyperspectral EO data. For the cropland use cases, the product developments will need to be preceded with data augmentations to increase the spatial and temporal resolution.

Given the exploratory nature of the ARIES project, and the unknowns on how thermal and hyperspectral data can contribute to the user requirements, no concrete product specifications can be defined at this stage. It is foreseen that at the end of the project, the product specifications can be further detailed based on the findings of the ARIES project, with a better understanding of the possibilities and limitations of the thermal and hyperspectral EO data.

6 System and operational requirements

Given the fact that the innovative EO analysis techniques to be developed within ARIES will be deployed on the Food Security TEP platform and will also be made available to the African users through the same platform, the system requirements within ARIES will be mainly determined by the computational demands of the algorithms to be developed and the spatial and temporal characteristics of the EO input data, rather than by the African users themselves.

From the users' perspective, there is not only a need to get easy access to any thematic end product as to be developed within the ARIES project, but also to the thermal and hyperspectral EO input data. This was especially highlighted by RCMRD, who wants to explore the potential of these new data sources further. We are convinced that, by providing the African users early access to the Food Security TEP platform, along with a dedicated training session, we will be able to meet this requirement.

With regards to the distribution of the end products to the users, it has become clear from our interviews that there is a need to deliver pixel-based products in raster format (.tif) for further integration of the products in the users' workflows and activities, but also map overviews (for instance in PDF format) to enable clear communication to non-GIS-experts.

7 Conclusion

In summary, it can be said that the involved users are looking forward to collaborate with the project. Their engagement needs to be ensured throughout the project. This could be done through sharing of data sets, but also technical discussion, validation of products etc. User also already raised a point on availability of the data intermediates and input data, to perform testing and data analyses themselves.

Based on the user requirements analysis, it can be said that there is a need for performant drought indicators at different scales. There is a large range of potential use cases for the ARIES results, however it is clear that ARIES products are considered inputs to a lot of these applications, rather than the final EO product (e.g., irrigation management based on drought onset indicators).

Further finetuning of the requirements and expectations of the users will be done throughout the project, to ensure the relevance of the research results, as well as the engagement of the users.