EO Africa // ARIES

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	VISTA Remote Sensing in Geosciences GmbH (VISTA) Vlaamse Instelling voor Technologisch Onderzoek, Naamloze vennootschap (VITO) Luxemburg Institute of Science and Technology (LIST)

ESA STUDY CONTRACT REPORT

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This document reports on the captures the major findings of the project and their policy relevance.

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Content

List of Acronyms

ACF/AHH	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
CSA	Climate-smart agriculture
ECOSTRESS	Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station
EnMap	Environmental Mapping and Analysis Program
EO	Earth Observation
ESA	European Space Agency
EU	European Union
GHG	Greenhouse gas
LAI	Leaf Area Index
LST	Land Surface Temperature
NPV	Non-photosynthetic active vegetation
PRISMA	PRecursore IperSpettrale della Missione Applicativa
ROSE-L	
SAR	Synthetic Aperture Radar
SIFAZ	Sustainable Intensification of Smallholder Farming Systems
SM	Soil Moisture

1 Introduction

Within ARIES the consortium partners, supported by the African Early Adopters, have developed and tested innovative indicators derived from Earth Observation (EO) data and related to crop productivity and crop water stress at resolutions ranging from 20 to 70 m, mainly in support of assessing impacts of drought on the agricultural sector. Indicators have been developed using high-resolution hyperspectral and thermal precursor missions, in preparation for similar operational missions to be launched within the next 5 years.

Early in the project, a Policy Traceability Matrix has been constructed, summarizing the major policies in place related to natural disasters (and particularly drought) at international, continental and country scale for the three target countries in the project (Zambia, Niger and Kenya). The current Policy Highlights document will focus more on the potential impact of the developed indicators (and our enhanced EO-based monitoring capabilities provided by the upcoming satellite missions in general) in light of recent agricultural policy frameworks. This analysis is restricted to Zambia and the Sahelian region (represented by Niger), two distinctively different use cases in terms of agricultural practices and environmental challenges.

2 Policy Relevance: Zambia

2.1 Current State of Agriculture in Zambia and Main Challenges

Zambia's agricultural sector remains predominantly small-scale, with approximately 80% of cultivated land managed manually, a mere 5% using machinery, and 15% utilizing animal traction. This reliance on labour-intensive methods restricts productivity, leaving farmers vulnerable to external stresses like climate variability. The Zambian government launched the National Agricultural Mechanization Strategy (2024-2028) to counter these limitations, aiming to enhance productivity through mechanization and climate-smart agriculture. However, persistent issues—such as low productivity, water scarcity, and limited technological access—hinder smallholder farmers' ability to scale their operations sustainably.

EO (Earth Observation) technologies have the potential to support these efforts by offering insights into land use, crop production, crop water stress, and crop health. Especially upcoming hyperspectral and thermal missions, delivering data at ever increasing thematic, spatial and temporal detail, can provide actionable intelligence to inform national policies, promote mechanization, and guide sustainable practices.

In the following sections, we illustrate the potential contributions of such new missions for different aspects in the domain of agriculture, specifically for the country of Zambia, based on the discussions between the project team and local project partners in the country.

2.2 Impact of Droughts and Improved Water Management

The recent drought during the 2023/24 season severely affected Zambia, impacting 1.1 million farming households and destroying over 980,000 hectares of maize. The drought emphasized the need for robust water management strategies and drought resilience frameworks, as was clearly underpinned in February 2024 by the current president, Mr. Hakainde Hichilema, when he declared the ongoing drought as a national disaster and emergency (Hichilema, 2024). The countermeasures identified to cope with this national crisis included expansion of irrigation schemes in the short term and aggressive investments in water harvesting and technology to support irrigation and crop productivity improvements on the longer term. Yet, one clear challenge in this regard entails the competition of water resources with the national energy sector, which is predominantly relying on hydropower plants. Also in this sector, the 2024 drought had severe implications, causing major power cuts throughout the country and thereby limiting farmers from irrigating their fields during the dry season (oral communication with AKTC and Mubuyu Farm). A clear example of this conflict is situated along the Kafue river (Figure 1). In this area in particular, the government asked farmers to reduce agricultural water consumption by 30% the coming years, to safeguard the hydropower dam further downstream.

Figure 1: Illustration of water resources conflict along the Kafue river. The hydropower dam is indicated using an orange pin. The red encircled area represents a site where irrigated agriculture has drastically expanded in the past few years.

Aside from the traditional **EO-based drought monitoring** frameworks based on low resolution (1 km to 100 m; e.g. FAO ASIS), which can in general terms inform policymakers about the major areas impacted by ongoing droughts, these recent disasters and conflicts clearly show the need for an increased focus towards detailed monitoring of **crop water productivity**, to achieve “more crop per drop”. While the ECOSTRESS-based drought indicator proposed by LIST can increase the resolution of the current low resolution approaches, the 20-30 m indicators developed by VITO and VISTA related to crop development and water stress allow to zoom in at individual field level and help individual farmers determining the optimal timing and quantity of irrigation to be applied. Based on their EO-based products, VISTA is already providing irrigation advice to some pilot farmers in the area, clearly demonstrating the potential of such digital services for farmers to save water while increasing or maintaining crop productivity.

Future missions like CHIME (Copernicus Hyperspectral Imaging Mission), LSTM (Land Surface Temperature Monitoring) and ROSE-L will enhance these capabilities, allowing for precise tracking of canopy water content, land surface temperature and soil moisture, and hence early detection of drought impacts. Such data can support drought-related interventions by identifying water-stressed regions in real time, improving irrigation efficiency, and guiding water restrictions. In conclusion, these missions will be instrumental for both large-scale and smallholder farmers in managing water sustainably under drought conditions.

2.3 Agricultural Mechanization Strategy

Given the low mechanization rate in the agricultural sector, the Zambian government launched its Mechanization Strategy early 2024, aiming to increase crop productivity through a hire-service model, where farmers with machinery offer services to nearby smallholders. Early Adopter AKTC plays a pivotal role in this model, training dedicated farmers and service providers in the use of agricultural mechanization tools. Effective deployment of EO data can further optimize this model by tracking crop phenology—capturing growth stages, land surface conditions, and crop health across regions. High-resolution multispectral imagery already allows for precise determination of **crop phenology**. Additional metrics derived from hyperspectral imagery, such as Leaf Area Index (LAI), canopy water content and especially **grain water content** (driving the optimal timing of harvest) could further enhance mechanization planning, enabling timely interventions that align with crop cycles, thereby maximizing productivity and resource use. These insights can drive targeted outreach and interventions, particularly in areas lagging in mechanization or struggling with drought and degraded soil conditions.

2.4 Crop Productivity and Climate-Smart Agriculture

Low productivity remains a major barrier for Zambia's 1.4 million smallholder farmers, exacerbated by limited access to technological advancements and resources. Government initiatives, including input programs, provide farmers with essential resources like seeds and fertilizers to boost production. EO data is critical in assessing these initiatives by monitoring **crop types**, **productivity levels**, and the success of input distribution in real-time. For instance, EO-based crop monitoring can help evaluate whether distributed inputs lead to improved yields and food security outcomes. Whereas the existing multispectral and SAR missions are sufficient to effectively mapping crop types, high-resolution hyperspectral and thermal missions are expected to play a crucial role in enhancing our ability to accurately monitor and predict crop productivity.

Climate-smart agriculture (CSA) is another key component of the recently launched mechanization strategy in the country. Through different cropping trials, early Adopter AKTC is providing valuable insights into which cropping practices can lead to increased crop productivity in a more sustainable way. EU-funded projects, such as the Sustainable Intensification of Smallholder Farming Systems (SIFAZ) with a €12 million investment, aim to support CSA adoption. EO data can track soil health, crop intensification, and CSA practice adoption, offering targeted support in high-need areas. Hyperspectral data from CHIME can assess parameters like leaf mass and **soil organic content**, while ROSE-L's soil moisture measurements contribute to water management in CSA contexts. By providing data on these indicators, EO helps inform farmers about best practices, making it easier for them to adopt sustainable, climate-resilient strategies.

2.5 Crop Forecasting

Accurate crop forecasting (which crops have been planted where and what are the expected yields?) is essential for efficient resource allocation and food security planning. Zambia's existing forecasting system relies on lots of manual work through field visits and is prone to inaccuracies, which has led to issues such as unnecessary maize imports due to overestimated deficits in the past. EO technologies can streamline crop forecasting by providing timely updates on **crop acreage, type, and yield**, significantly reducing the risk of misinformed decisions. EO data enables both the government and farmers' unions to access real-time insights, facilitating better policy-making and response strategies.

3 Policy Relevance: Sahel region

3.1 Context

The Sahelian region faces significant environmental challenges, including recurrent droughts and desertification. As a result, land use conflicts and security issues have arisen in the region, further exacerbating food security. In this section, we use the country of Niger as a representative use case for the Sahel region. With over 4 million households affected by food insecurity in 2022 due to consecutive failed rainy seasons, the Niger government has implemented several strategies to address these issues. Key policies include the National Rice Development Strategy (SNDR, 2021-2030) and the Small-Scale Irrigation Strategy (SPIN, 2015). Earth Observation (EO) data, such as high-resolution hyperspectral and thermal data, can provide crucial support in implementing and monitoring these strategies.

3.2 Drought Monitoring and Early Warning

Niger is already using EO data to monitor drought conditions through the AGRHYMET Regional Centre, which combines satellite data with ground-based measurements to forecast seasonal rainfall and drought risk. In 2021, for the first time, the government has used satellite early warning data to identify drought-affected areas to intervene early with unconditional cash transfers. The introduction of the ECOSTRESS-based drought indicator at 70 m resolution offers a more detailed view, and could be further complemented with the higher resolution indicators developed within ARIES (20-30 m) enabling authorities to zoom in on areas experiencing severe water stress. This level of detail allows for targeted interventions, such as the early distribution of drought-resistant seeds or adjusting irrigation practices. Future operational missions like CHIME, LSTM and ROSE-L will enhance Niger's drought monitoring capabilities, contributing to both **early warning systems** and **long-term drought resilience planning**.

3.3 Irrigation and Water Management

Niger's focus on expanding irrigated agriculture, particularly through the Small-Scale Irrigation Strategy (SPIN) and Niger's Irrigation Development Strategy (SNDI/CER), requires effective monitoring tools to ensure the sustainable use of water resources. As mentioned in the previous section, the crop productivity and water stress indicators proposed in ARIES can help tracking **water productivity** by measuring crop water use and assessing irrigation efficiency. This is critical in regions where water scarcity is a major concern and can help Niger achieve its goal of increasing the contribution of irrigated agriculture to the national GDP.

3.4 Land Use Conflicts: Cropland Mapping and Assessing Feed Availability

In the Sahel, land use conflicts are common between farmers and nomadic herders, particularly during the dry season when fields are traditionally opened for grazing. However, increasing food insecurity has led many farmers to fence off their land for year-round cultivation, resulting in tensions. EO technologies can help monitor changes in land use, providing automated cropland mapping that can track the expansion of cultivated land and the encroachment of grazing areas. To gain a better understanding of this problem, AGRYHMET is already publishing their land use atlas every 3 years. Generation of these **land use maps** however currently greatly relies on manual mapping work based on very high resolution satellite data (oral communication AGRYHMET). Such workflows could be automated to a large extent using ongoing initiatives such as the ESA WorldCereal project.

To support the nomadic herders in planning their grazing routes, organizations such as AGRYHMET and Action Contre la Faim (ACF) are already releasing monthly to bi-monthly bulletins based on a combination of EO data and field observations. Such bulletins typically contain spatially-explicit information on climate conditions, biomass productivity, crop conditions and even socio-economic conditions in the region (ACF reports; example of AGRYHMET report). ACF hosts these spatial datasets in a GIS web application (geosahel.info; see Figure 2) and is planning to launch a smartphone application (Pastonavigator) to bring these data to the targeted end user in an efficient way.

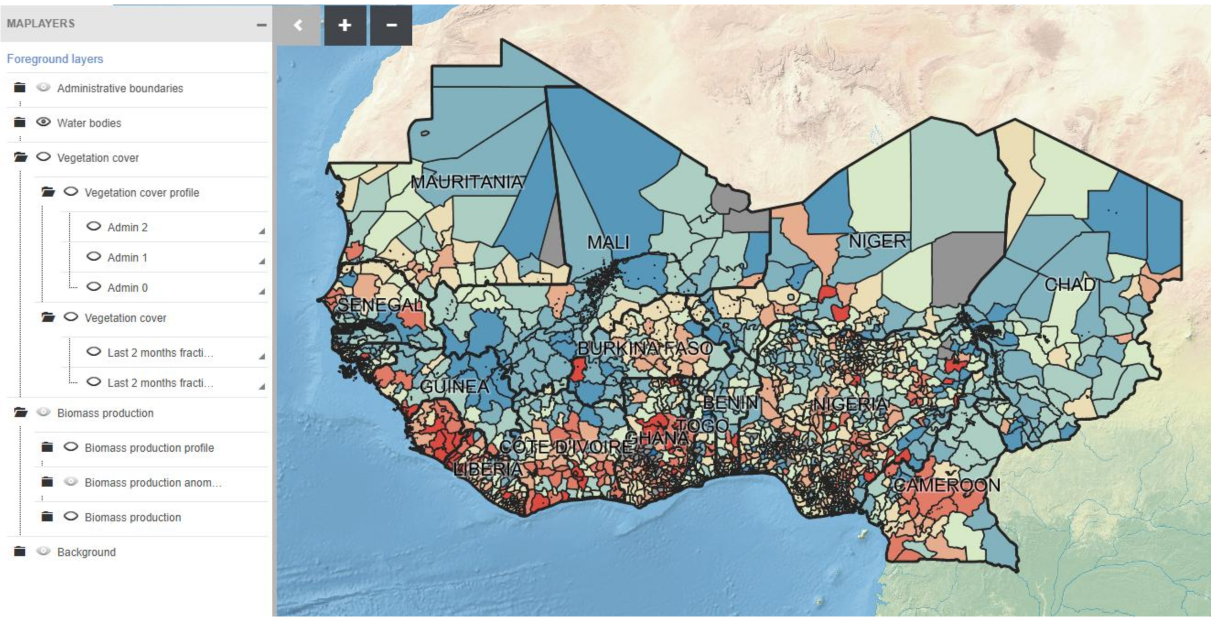

Figure 2: Geosahel application for agro-pastoralists, launched by ACF, containing spatially-explicit information on vegetation cover, biomass productivity and surface water availability (geosahel.info).

One specific additional requirement for these agro-pastoralist information and surveillance systems, identified by both ACF and AGRYHMET, is information on the availability of dry (grassland) biomass during the dry season. Currently, **dry biomass quantity** is challenging to estimate based on existing operational satellite missions. ACF is already using the non-photosynthetic active vegetation (NPV) product from MODIS to this end, but there is definitely room for improvement here, both in terms of thematic accuracy and spatial resolution. Especially high-resolution hyperspectral data is expected to play a pivotal role here, as these data contain specific information related to lignin and cellulose content.

3.5 Input Programs and Seed Policy

Niger's National Seed Policy (PSN, 2012) and Decentralized Input Supply Strategy (SIAD, 2013) aim to improve agricultural productivity by ensuring access to quality seeds and inputs to all Niger farmers. EO data can help monitor the distribution and use of these inputs, especially by offering insights into **crop type distribution, crop health and crop productivity patterns**. This information can support the government's efforts to create a resilient agricultural system capable of withstanding climate change and drought, by directing most on-ground efforts to those regions showing limited uptake of provided inputs.

3.6 National Adaptation and Climate Change Strategies

As mentioned earlier, the Sahelian region faces direct consequences of climate change, mainly due to desertification. Niger's National Adaptation Plan to Climate Change (2022-2026) and National Strategy and Action Plan on Climate Change (SNPACVC, 2014) outline the country's goals for building resilience to climate change. EO data will be crucial in tracking the success of these initiatives, particularly in monitoring **GHG (greenhouse gas) sequestration**, crop resilience, and the effectiveness of mitigation measures. One concrete application of the developed indicators within the ARIES project includes the assessment of reforestation projects (cf. Great Green Wall). Especially thermal indicators can help here to assess the **drought resistance** and hence suitability of different tree species.

4 Conclusion

Even though characterized by different agro-climatic, geographical and environmental conditions, the agricultural sectors in both Zambia and the Sahel region face similar challenges, i.e. low agricultural productivity, lack of irrigated agriculture, conflicts on land use and water resources and adverse impacts of climate change. Throughout this document we highlighted various ways in which EO data can support in monitoring and enhancing the effectiveness of agricultural policies, fostering long-term food security and sustainable land management. Reliable, objective and detailed information on crop types, production, phenology, water stress and health can directly feed into improved land use maps, drought early warning systems, crop water productivity services, agro-pastoralist guidance systems, insurance schemes, seed/input dispersal strategies, climate change mitigation projects and agricultural mechanization policies. Despite this large potential, the adoption of EO data is currently limited in both regions. Capacity development and knowledge transfer therefore remain crucial in boosting the uptake of EO data in the agricultural sector across the continent.

Future operational missions like CHIME, LSTM, and ROSE-L will be offering even more detailed measurements of crop health, water usage, and soil conditions. By integrating EO data into policy-making and enforcement, Zambia and Niger can ensure that their agricultural sectors grow sustainably and remain resilient in the face of climate challenges.

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