EO Africa // ARIES

D06 – Validation Methodology

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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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<tr><td colspan="4">ABSTRACT:

This document describes the validation methodology, validation data and validation results.

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Content

Figures

Tables

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
ECOSTRESS	Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station
EO	Earth Observation
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
LAI	Leaf Area Index
LST	Land Surface Temperature
R&D	Research & Development
RCMRD	Regional Centre for Mapping of Resources for Development
SAlib	Sensitivity Analysis Library

1 Introduction

EO AFRICA (African Framework for Research Innovation, Communities and Applications) is a research and development initiative by ESA. It focuses on building African-European R&D partnerships and the facilitation of the sustainable adoption of Earth Observation and related space technology in Africa.

Within “ARIES” experimental EO analysis techniques will be developed and validated, addressing water management and food security in Africa.

To ensure the products developed within the project serve the needs of future users the techniques will be developed closely together with African Early Adopters. These five organizations are covering east (AfriGeo, EO research group within the Regional Centre for Mapping of Resources for Development in Kenya & the Regional Centre for Mapping of Resources for Development in Kenya itself), west (AGRHYMET Regional Centre and AAH Action Against Hunger in Niger) and southern (Zambian Agricultural Knowledge and Training Centre LTD in Zambia) Africa. Thereby the developed algorithms and approaches can be validated, tested and evaluated in different geographic regions with different climatic conditions and agricultural practices.

The current document aims to provide an overview of the validation methodology (Section 2), available validation data (Section 3) and validation results (Section 4) for all indicators developed within the framework of the ARIES project.

2 Validation Methodology

2.1 Direct Validation

Direct validation using field measurements will only be applicable to a few of our proposed products, for which measured data is available. For example, plant water content can be measured by the African partners by cutting a biomass sample and measuring the weight before and after drying to derive the difference between wet and dry biomass and thus the plant water content. Plant parameters that need more complex sensors to derive them in-situ like e.g., leaf area, are more difficult to procure, but can at least be compared to other leaf area products from multispectral satellite data.

2.2 Indirect Validation

Many of the proposed drought indicators cannot be directly measured on the field and are therefore hard to validate directly through field measurements. After careful interpretation of the computed drought indicators, parameters such as onset, duration and intensity of drought can be derived and qualitatively evaluated through observations made by the Early Adopters and/or existing drought monitoring platforms operating at low spatial resolution such as FAO's Agricultural Stress Index System. For this, already collected information on crop health/development, biomass production, yield, irrigation activities, and drought conditions will be made available for all reference sites of the Early adopters (Niger, Kenya, Mali, Senegal, Zambia; see Section 3.1 for full overview). By cross-checking temporal/spatial patterns in crop/pasture productivity with identified periods of ecosystem/crop water stress, we can obtain a good indication on the accuracy and usefulness of the developed indicators.

Although the final products might be hard to validate, there are some intermediate steps in the product generation workflows for which a more in-depth understanding of the accuracy can be gained. One example includes the evaluation of the Land Surface Temperature (LST) sharpening step, proposed to generate the high-resolution crop water stress indicators. Sharpened LST data derived from Sentinel-3 can be compared with high resolution LST data derived from both ECOSTRESS and Landsat 8/9 data. Although a direct comparison and strictly quantitative validation approach would be hard to obtain (due to differences in overpass time between the sensors), a more qualitative comparison of spatial and temporal patterns might already provide sufficient indication of sharpening accuracies.

2.3 Global sensitivity analysis

Aside from the (in)direct validation of the computed indicators and dedicated parts of the workflows used to generate the products, a global sensitivity analysis is planned to gain a better understanding of the primary driving factors behind the proposed indicators.

Global sensitivity/uncertainty analysis of the proposed drought indices due to uncertainty in input variables will be calculated using SOBOL-based uncertainty analysis (SAlib). Uncertainty analysis will be based on an assumed systematic error (caused by a potential bias in the input variables) at the study sites. In a first step, based on the literature, the error bounds of each input variable used for individual drought index estimation will be defined. The error samples (perturbation) within these bounds will be generated using the Saltelli sampling scheme (using the python package SALIB53) or in Matlab using appropriate packages. Each error sample will be added to the input variables. Actual input variables combined with perturbed input variables will be used to estimate the drought indices. The obtained range in values of the individual drought index based on the perturbation will be used to calculate the uncertainty of our newly developed drought indicators.

2.4 Proposed Products and Envisaged Validation Methods

In Table 1 we provide an overview of the validation approaches which will be applied to each of the proposed indicators to be developed within ARIES.

Table 1 Proposed products and envisaged validation methods

Product	Validation Method	Validation Data Description
Green leaf area	Direct	LAI products from other satellites
Green leaf area	Indirect	In-situ measurements FLUX tower / biomass
Leaf / Plant water content	Direct	In-situ measurements of dry and wet biomass
Ecosystem water stress (70m)	Indirect	Comparison with biomass estimates derived from (1) field surveys and (2) low resolution satellite data analysis
High resolution crop water stress (10 – 20m)	Indirect	High resolution thermal satellite data to validate intermediate LST estimates. In-situ field-scale observations on biomass production, yield and crop water

		stress to validate the final crop water stress product.
Drought susceptible area	Indirect	In-situ field-scale observations on biomass production, yield and crop water stress
Canopy water content (30m)	Direct	In-situ measurements of dry and wet biomass
Canopy water content (30m)	Indirect	Intermediate steps in the product generation (green leaf area and leaf water content) can be validated through direct and indirect validation methods

3 Validation data

3.1 In-situ data

All associated Early Adopters either conduct or have access to agricultural tests sites (see Figure 1) in which they gather data relevant for validation of the planned innovative EO algorithms and products.

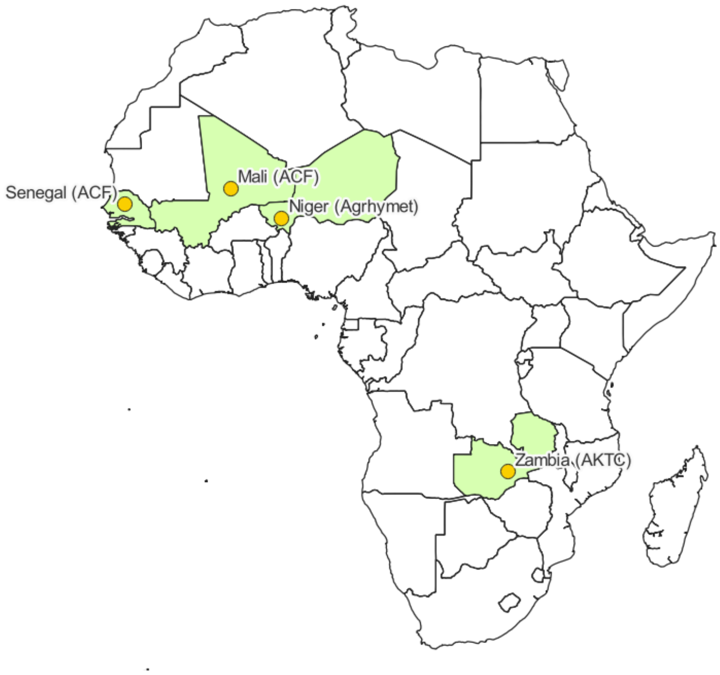

Figure 1 ARIES test sites in southern and western Africa

An overview of currently available in-situ reference data is presented in Table 2. The ground truth data was already collected in recent years and surveying continues so that validation data is available for the entire period covered by the project. This also ensures that in case no further data acquisitions of ECOSTRESS data can be conducted for the areas of interest during the project phase, historic data of recent years can be used to validate the EO algorithms and products.

Table 2 Available reference data sets for the African test sites

Organization	Country	Data available	Available variables	Years
ACF	Mali	Data on irrigated croplands	Crop type, health and yield	?
	Senegal	Field campaigns conducted by CSE (Centre Suivi Ecologique), 61 active sites	Crop type; Crop health; Drought conditions; Pasture productivity	Since 1988, ongoing
AGRHYMET	Niger	Weather station data and field surveys, including multispectral UAV campaigns	Crop type, crop yields, fodder yields, phenological monitoring of vegetation, rainfall data, biomass estimates from UAV imagery and low-resolution satellite imagery	Ongoing for many years. Period of interest (2018 – 2022) is covered.
AKTC	Zambia	Data of test fields, several fields available and regularly monitored, irrigated and non-irrigated areas, weather station data, photographs	Crop type; crop health; drought conditions; Information if crops were irrigated or non-irrigated; information on agricultural practice (conventional/regenerative); soil moisture; soil temperature; rooting depth, infiltration rate; dry and wet biomass, local meteorological data	Available for project time
RCMRD	Kenya	Data collected at several sites throughout Kenya	Unknown but stated to support crop mapping and mapping of drought conditions	

With more validation data available for some of the test sites and less for others, incremental algorithm and product development and the initial validation will focus on certain test sites. The final products can then additionally be tested in one or several sites, that have not been used in development. This will provide a measure of transferability.

3.2 Other data sources

Thermal data from Landsat 8/9 can be used in a qualitative comparison with LST products derived from Sentinel-3 and/or ECOSTRESS. Given the different spatial resolution and overpass times, direct validation using Landsat LST data will not be possible. Still, comparing major trends in LST over longer time periods between these data sources will provide us at least with some indications with regards to the validity of the thermal sharpening techniques to be adopted and developed within the project.

Low resolution satellite products, such as vegetation products from the Copernicus Global Land Service (e.g., dry matter productivity, LAI at 300 m resolution) and biomass/evapotranspiration products from FAO's WaPOR data portal (100 – 250 m) can also be used for validation in test sites with little or unsuitable in-situ data available, e.g., validation of green leaf area in pastoral test sites. Due to the products relatively coarse spatial resolution, especially in comparison with the products we are aiming to develop, their main use will be as an indicator for the temporal accuracy of our results. This will allow us to assess at least some aspects of the quality and usefulness of our products even in locations with little validation data available.

4 Validation Results

Validation results will be added in the next instalment of this report (D06_VM_FR_I) due at M2 (M1+14).

5 Conclusion

All African partners, with exception maybe of RCMRD who has been hesitant in making firm statements, have provided one or several test sites for which they have a diverse set of validation data available. The data ranges from simple drought condition monitoring to detailed measurements of biomass, soil moisture and yields. The data have been collected for several years and the collection is continuing. In some cases, there is the possibility to co-determine and influence which kind of data should best be gathered at what point of time in order to benefit both ARIES and the African Users.

Not all of these data sets are useful for direct validation of our results. Therefore, we will be using a broad validation strategy making use of both direct and indirect validation of products and intermediate steps in the product generation. Additionally, to this a global sensitivity analysis is supposed to reveal the primary driving factors behind the proposed indicators. It is also part of our strategy to prioritize development and initial validation in test sites that have the most useful validation data available, using the remaining test sites in order to measure transferability. Other data sources (e.g., vegetation products from the Copernicus Global Land Service) are also part of ARIES's validation strategy.

The focus in the next phase of ARIES will be on acquiring these validation data sets from our African users and ensuring data collection taking place during the project time is set up so that the African users and ARIES can benefit as much as possible.