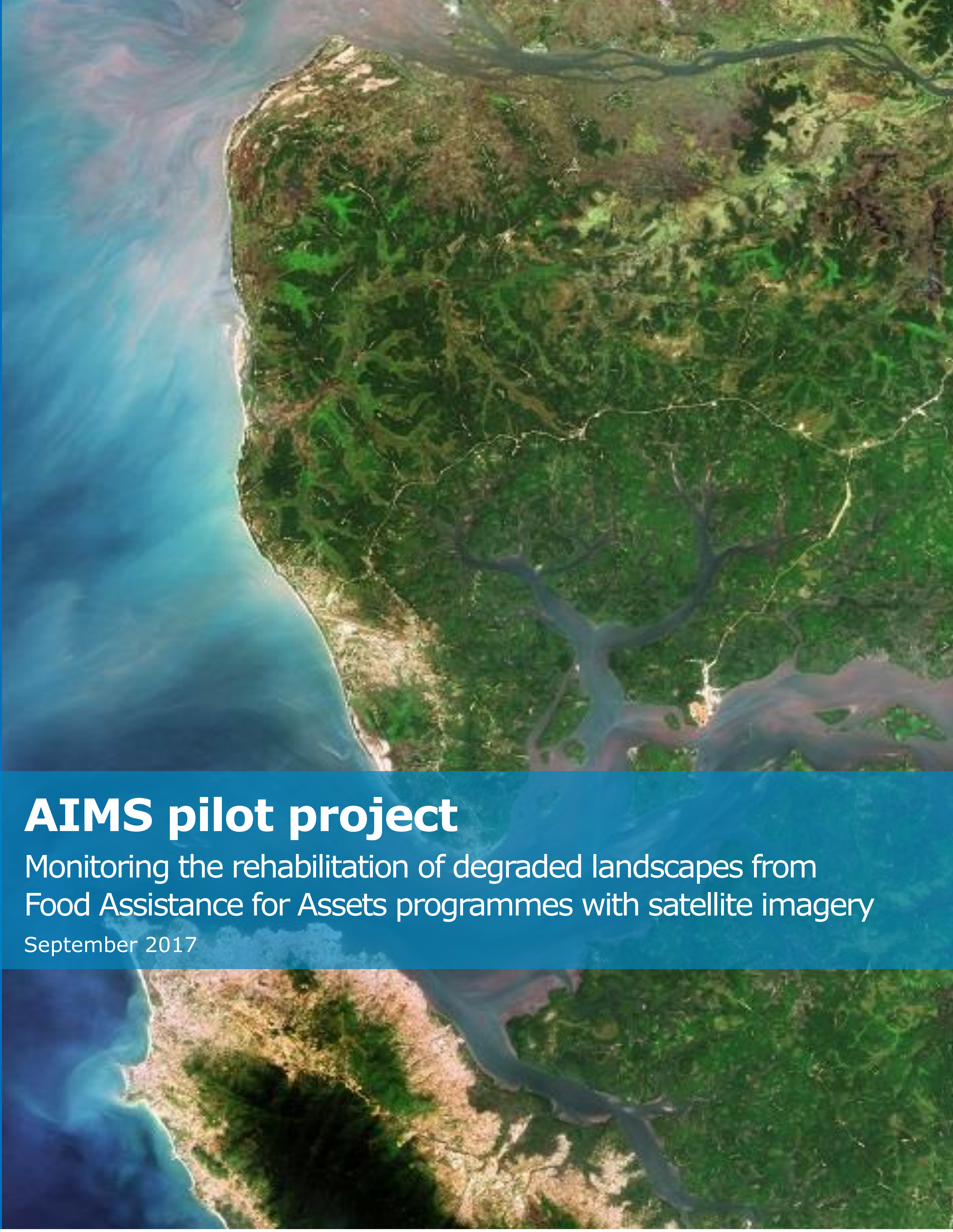
Fighting Hunger Worldwide



AIMS pilot project

Monitoring the rehabilitation of degraded landscapes from Food Assistance for Assets programmes with satellite imagery

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WFP

World Food Programme

wfp.org

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Satellite images showing rural road construction in Bagthala (Nepal)

Asset Impact Monitoring System (AIMS)

Over the past decade, Earth Observation (EO) satellite technology has proved to be a powerful tool for landscape monitoring. Medium/high resolution imagery, much of it available on open platforms, offers an ever-growing archive of easily accessible data. In addition, new satellites that were recently launched are capable of acquiring images more frequently, offering increased EO data quality and improved spatial coverage which extends to most of the globe.

Through these technological developments, satellite imagery has become an effective method for building evidence of the physical impacts of WFP's interventions, capable of **monitoring long-term and large-scale landscape rehabilitation**.

The **Asset Impact Monitoring System (AIMS)** project uses satellite imagery and landscape monitoring techniques to monitor the positive changes of WFP's Food Assistance for Assets (FFA) and engineering programmes on local landscapes.

In particular, where there are limited options for detecting the effects of FFA interventions – for example, due to access constraints – the integration of satellite technology offers a solution to assess landscape rehabilitation to help cope with a lack of timely, long-term, homogeneous and reliable ground information to understand such changes.

The AIMS project, implemented by WFP's Vulnerability Analysis and Mapping Unit (VAM), the Asset Creation and Livelihoods Unit, and supported by the Innovation Accelerator in Munich, was built upon previous experience from a similar project carried out in Somalia by the WFP East Africa Regional Bureau in Nairobi.

The AIMS project underwent a pilot phase (February — July 2017), which determined that satellite technology can better support WFP's work in three ways:

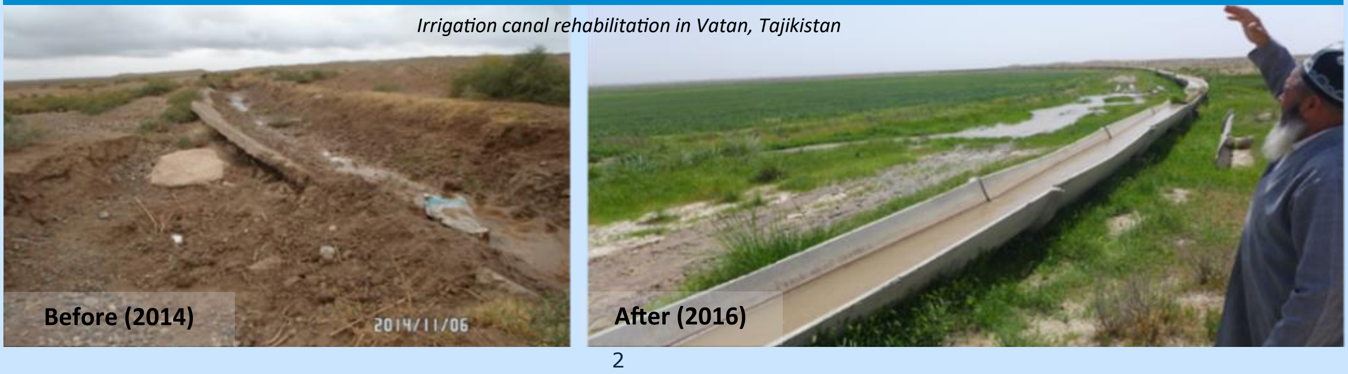
1) Monitoring the rehabilitation of degraded landscapes linked to FFA programmes;
2) Quantifying the regenerative impact of FFA on the local environment over time and in 'shock' years;
3) Identifying examples to advocate for the positive impact of WFP's FFA programmes on water availability and vegetative cover.

Food Assistance for Assets (FFA)

The most food-insecure people often live in fragile and degraded landscapes and in areas prone to recurrent natural shocks and other risks. **In collaboration with communities, governments and partners**, WFP focuses efforts on strengthening the livelihoods of the food-insecure, building resilience through its Food Assistance for Assets (FFA) programmes. In the short-term, FFA addresses the immediate food needs of the most vulnerable populations through cash, vouchers or food transfers, while promoting the **building or rehabilitation of assets that will improve long-term food security and resilience**.

The FFA approach puts **communities and people at the centre of planning** while strengthening the capacities of the government and making sure quality standards for assets are met. With the proper understanding of the local context, landscape and livelihoods, assets and complementary activities—such as training programmes—are integrated and matched to the scale of the problems that affect communities, ensuring sustainable success. The assets built or rehabilitated—such as forests, water ponds, irrigation systems and feeder roads—help stabilize and restore land, reduce disaster risks and increase food productivity.

In 2016 alone, more than 10 million food insecure and vulnerable people benefited from WFP's FFA programmes across 52 countries



Irrigation canal rehabilitation in Vatan, Tajikistan

Before (2014)

After (2016)

AIMS: Pilot Phase

The AIMS team worked through a step-by-step approach during the pilot phase:

1. Identify the types of interventions potentially traceable from space

Six distinct FFA activity types were initially identified. The following table presents these activities and examples of expected outcomes for each of them (although these will be context-specific):

Project type	Expected outcomes
Soil & water conservation	Vegetation cover increase ('greening') Increased water availability Increase in soil moisture
Feeder roads	Increase in constructions along the road Change in land use along the road (new cultivated lands) Increase in vehicles using the road
Water catchments	Increase in water quantity in the catchment Catchment filled during the dry season Increase in agricultural activities around the pond (e.g. vegetable gardens) 'Greening' after implementation
Irrigation canals	Increase in cultivated area Improved productivity Increase in number of productive cycles
Forestry	Vegetative cover changes Increase in soil moisture
Gully control	Stabilization of gully banks Water availability Vegetative cover changes (excluding invasive species)

2. Identify the countries on which to focus the analysis

To start the pilot phase, 20 countries across all regions were selected based on the following criteria:

- Focus on recent FFA implementations, from 2011 onwards, thus targeting countries that applied the latest FFA approach (focusing on the assets and their impact on people rather than previous approaches focusing on the work - e.g. Food for Work);
- Countries that implemented at least one of the FFA activities among the six project types previously identified.

Once the countries were selected, information on the assets was compiled and verified. The dates of intervention (start and end), the precise coordinates of the assets and the area of impact expected are the minimum requirements for running analyses and extracting results based on EO data. This information is needed to define essential factors for the analysis, such as the period of the year during which satellite imagery must be acquired in order to better detect the corresponding outcome. Similarly, the start and end dates of the intervention determine which satellites and sensors can be considered. Moreover, the assets' coordinates define the type of climate (dates of rainy season, number of growing seasons) and crop types.

3. Conduct tests involving satellite imagery analyses on the various project types, in the different countries

The test phase involved exchanges with country officers and the use of different sensors, remote sensing algorithms and processing tools to find the most suitable methodology for each type of FFA initiative in the varied environments of the 20 countries.

The methodology is based on: (1) a qualitative analysis, through the photointerpretation of Very High Resolution (VHR) satellite imagery and (2) a quantitative analysis, using lower resolution imagery (Landsat, Sentinel, Modis) to assess the large-scale impact in the longer term.

4. Identify key results across countries

After the tests conducted at the beginning of the pilot, five projects were selected for further analysis. These projects are all implementing different types of assets, and located in different environments. From April to June 2017, deeper analyses of these five FFA projects were run to produce the results presented in this document.

5. Recommendations and opportunities for future replication

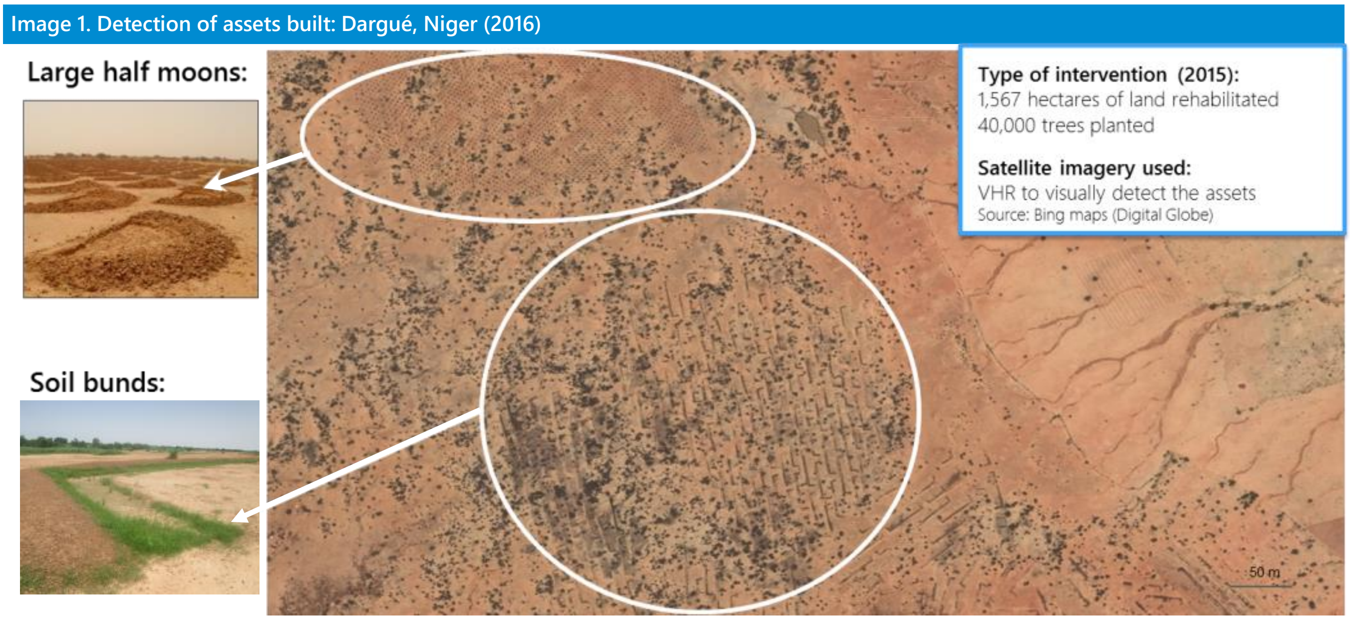
The results so far demonstrate the value of analyzing satellite images to monitor physical changes induced by FFA activities. Limitations of using satellite imagery are also evaluated. Eventually, recommendations for a wider, cross-organizational implementation will be discussed.

Detection of a multipurpose pond constructed in Mariem West, South Sudan - 2013. Photo taken in 2016.

Image Source: U.S. Department of State; Copyright: © Digital

In the following pages, the key findings from the AIMS pilot phase are presented.

Image 1. Detection of assets built: Dargué, Niger (2016)



Type of intervention (2015):
1,567 hectares of land rehabilitated
40,000 trees planted

Satellite imagery used:
VHR to visually detect the assets
Source: Bing maps (Digital Globe)

AIMS: Key Results

Key results show how the use of satellite imagery can help assess physical changes linked to FFA programmes. Focusing on the specific types of assets previously identified across different environmental contexts, the presented results highlight: (1) the detection of the assets themselves, (2) the detection of induced changes in landscapes over time; and (3) the detection of changes in vegetation and other natural resources during ‘shock’ years (in terms of climatic conditions).

Out of the 20 potential countries, five were eventually chosen to provide examples across the various project types identified and implemented in different environmental contexts:

- **Niger**: Guidan Roumdji region - soil & water conservation activities which aims to rehabilitate land and improve agricultural productivity;
- **Afghanistan**: Gamberi desert - reforestation activities;
- **Sudan:** Hamesh Koraib - check dam rehabilitation for harvest sediment load to grow trees and shrubs;
- **South Sudan**: Pageri-Magwi - engineering feeder road rehabilitation to increase constructions and cultivated land along the road (not FFA);
- **Tajikistan**: Vatan - irrigation canal rehabilitation to increase water availability for cultivation and improve productivity during the dry season.

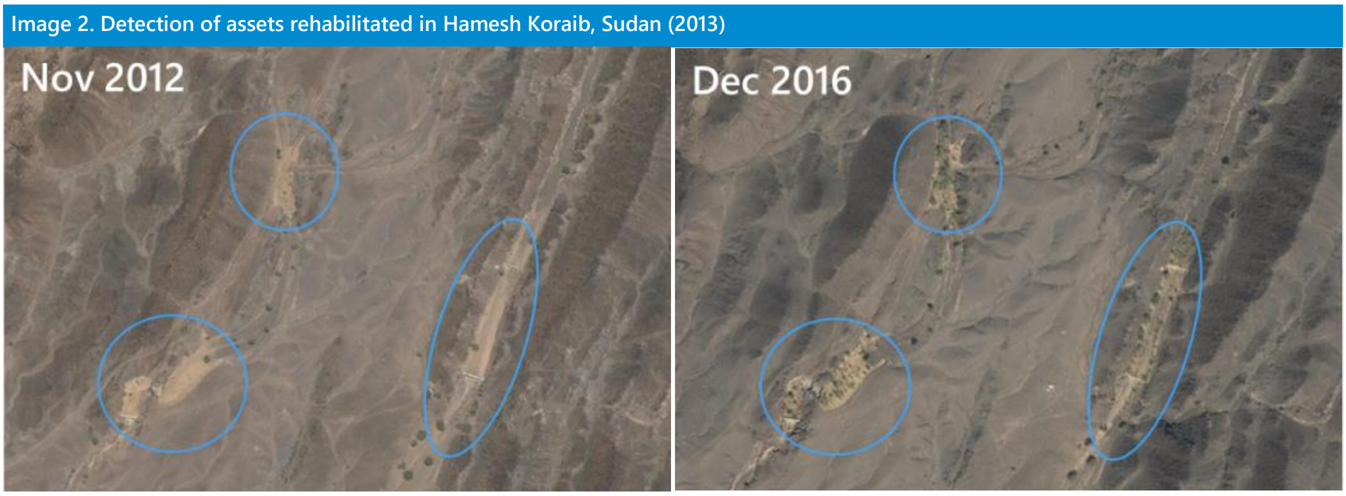
1. Detection of the assets built

Very High Resolution (VHR) satellite imagery was used, when available, in order to check built or restored assets and whether they had been maintained over time. For this, the appropriate satellite images were acquired before and after the asset was implemented.

Image 1 shows the assets in Dargué, in the Guidan Roumdji region of Niger, built in 2015. Large half-moons and soil bunds, visualized with VHR satellite imagery, enable retention of water in slopes and thus rehabilitate and protect the land. In a second phase, tens of thousands of trees were planted in the area thanks to these soil conversation measures.

Image 2 shows the FFA site in the Hamesh Koraib locality in Sudan, where six dams were rehabilitated in 2013 in order to re-green this arid area and increase its potential for agriculture and domestic use. There are five check dams (60 m^3 each) and one rock-fill dam (120 m^3). VHR imagery zooms in on three assets at two different points in time (November 2012 and December 2016, respectively), showing the assets before and after the 2013 intervention. A significant increase in shrubs and trees is visible on the 2016 image.

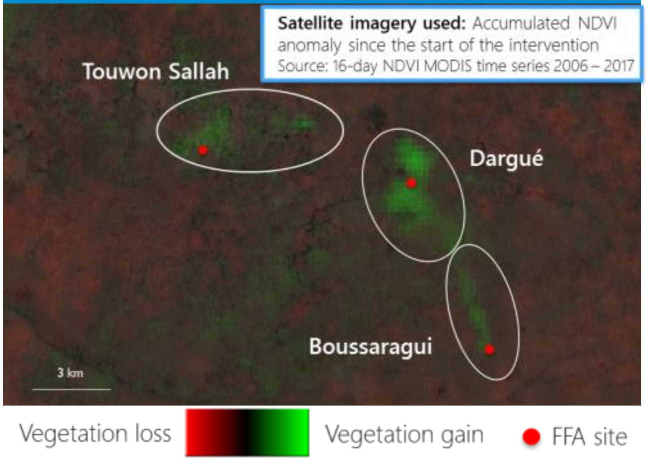
Image 2. Detection of assets rehabilitated in Hamesh Koraib, Sudan (2013)



2. Detection of rehabilitation of degraded landscapes over time

In countries where the assets were shown to be present and maintained over time (described in the previous section), a deeper analysis based on lower resolution but more frequent satellite imagery was carried out to determine if longer-term changes could be observed and linked to the expected objectives of the FFA activities. Specific years before the intervention were identified to compare how the rehabilitation of the landscape around the asset has changed since the FFA intervention.

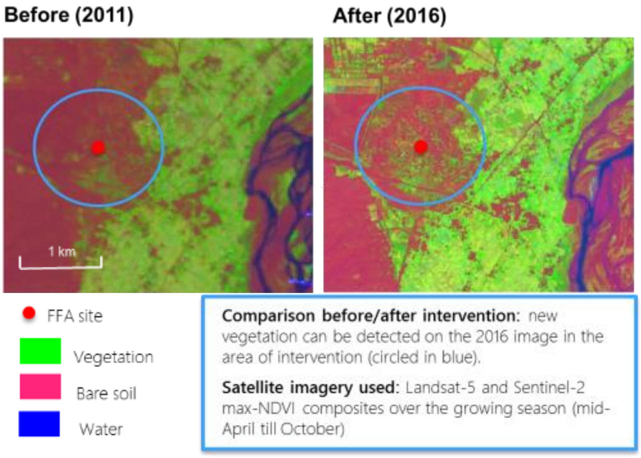
Image 3. Changes in vegetation cover in Dargué, Boussaragui, Touwon Sallah after 2015 (Niger)



Satellite imagery used: Accumulated NDVI anomaly since the start of the intervention
Source: 16-day NDVI MODIS time series 2006 – 2017

In **Image 3,** a significant increase in vegetation cover can be detected in the areas of the three FFA locations. The Normalized Difference Vegetation Index (NDVI) is used as a proxy of vegetation cover health.
The site of Dargué, where both half-moons and soil bunds were implemented, shows the highest vegetation gain according to Image 1. There is also evidence of re-greening in the areas of Boussaragui and Touwon Sallah, where mostly half-moons were implemented.

Image 5. Detection of changes in landscape between 2011 and 2016 in Gamberi desert, Afghanistan



Comparison before/after intervention: new vegetation can be detected on the 2016 image in the area of intervention (circled in blue).

Satellite imagery used: Landsat-5 and Sentinel-2 max-NDVI composites over the growing season (mid-April till October)

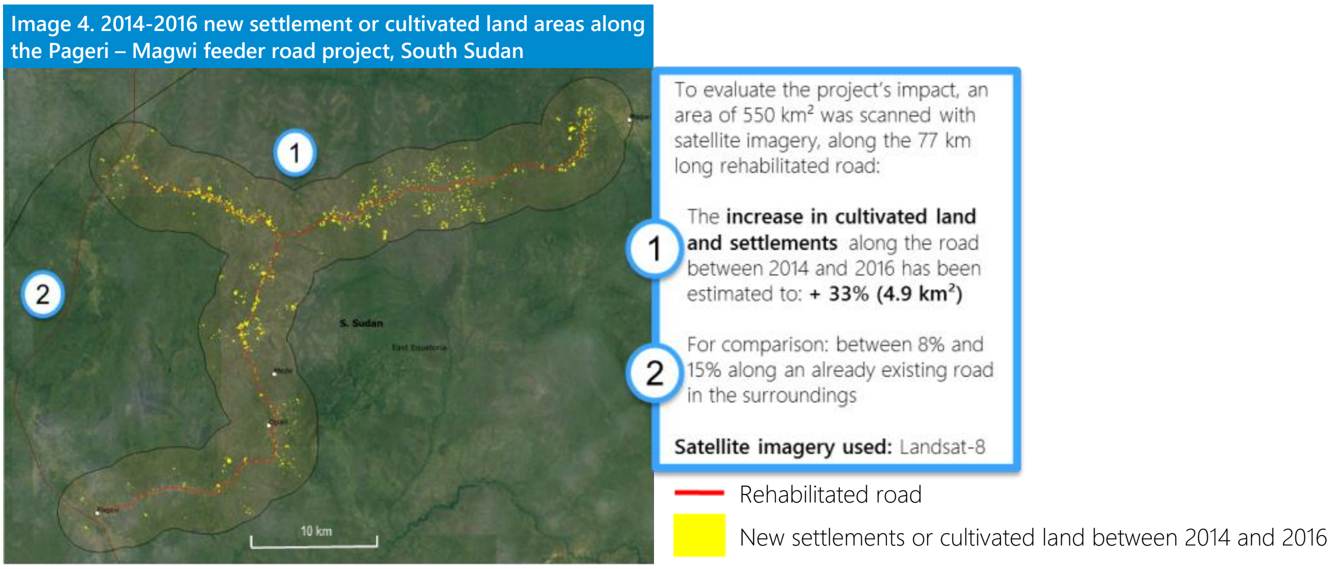
Focusing on the engineering feeder road project undertaken in South Sudan, which joins the towns of Pageri and Magwi and links to the Juba highway, **Image 4** illustrates what land use change occurred in this large area after the intervention in 2015. About 1,500 km^2 was scanned with satellite images to detect the road.

The map highlights the areas detected as new settlements and new cultivated lands in 2016 along the rehabilitated road, which were not present in 2014. The increase is estimated at 4.9 km^2, corresponding to a 33% increase in settlements/cultivated lands along the road in two years. By comparison, an already existing road in the surroundings saw an increase of between eight and 15% in the same period.

Image 5: In the Gamberi desert area in Afghanistan, the comparison of two images from 2011 and 2016 imagery shows new vegetation in the area surrounding the FFA site. The green pixels in the 2016 image around the asset correspond to the 1,000,000 trees planted through the FFA project, from 2013 to 2015.

To further evaluate the environmental impact of FFA projects, the BACI (Before After Control Impact) statistical methodology developed by the Joint Research Center was applied. This approach compares changes in the area of intervention with natural changes in other surrounding areas having similar land characteristics. Therefore it quantifies the impact of the intervention and its significance.

Image 4. 2014-2016 new settlement or cultivated land areas along the Pageri – Magwi feeder road project, South Sudan



To evaluate the project's impact, an area of 550 km^2 was scanned with satellite imagery, along the 77 km long rehabilitated road:

① The **increase in cultivated land and settlements** along the road between 2014 and 2016 has been estimated to: **+ 33% (4.9 km^2)**

② For comparison: between 8% and 15% along an already existing road in the surroundings

Satellite imagery used: Landsat-8

3. Detection of rehabilitation of degraded landscapes during ‘shock’ years

In countries where satellite imagery was available during ‘shock’ years (droughts, floods, etc.) before FFA intervention, this imagery was compared with a ‘shock’ year (with similar characteristics) that occurred after FFA implementation to identify changes in the rehabilitation of the landscape around the asset during extreme climatic conditions.

Image 6 shows that in three locations in the Maradi region of Niger where FFA soil conservation measures were implemented in 2015, healthy vegetation (green on the map) is visible in 2016, delineating the shape of the interventions. Conditions in 2016 were drier than average in terms of rainfall, yet vegetation could be detected at all three FFA sites.

Prior to the FFA intervention in 2015, these areas mostly lacked vegetation, according to EO data. Even in 2013, which was considered a good year in terms of climatic conditions, the FFA sites showed little vegetation. However, a year after the intervention, in 2016, despite the dry conditions, those same areas are the ones showing vegetation, while the surroundings seem to have suffered vegetation loss (appearing in orange on the image).

Image 7 shows the summer crops in years before, during and after the FFA intervention along the 3.8 km canal that was rehabilitated in 2015, close to Vatan village (Jamoat Obshoron) in Tajikistan. 110 hectares of land could be detected as new crops in 2016.

2016 was a ’shock’ year in this area, in terms of rainfall and the vegetation index (NDVI). 2011 presented comparable anomalies values. However, the maps show that crops can be detected in Summer 2016, after the asset was created, while no vegetation is visible during the same period in 2011.

The findings from satellite images in Niger and Tajikistan suggest that these FFA sites have induced significant changes in landscape, even during shock years. Results should be further investigated on the ground with communities to better understand the economical and societal impact these changes have had.

Main Findings & Limitations

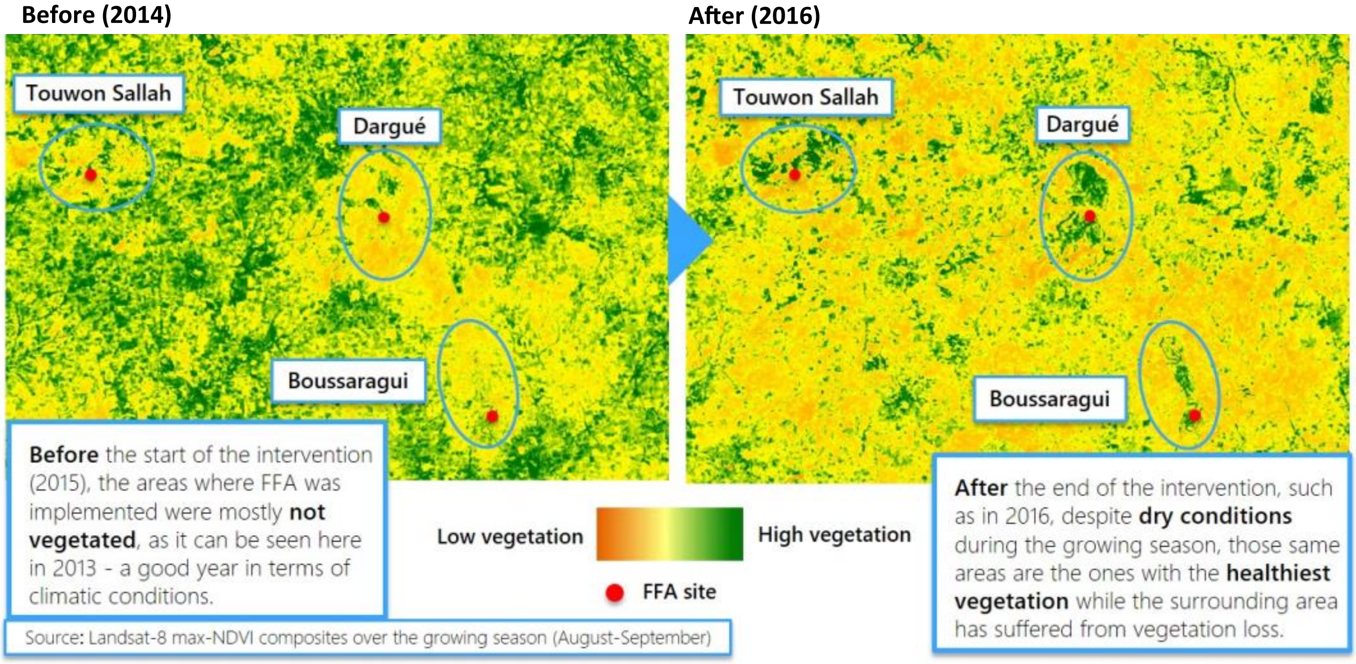
Main Findings

- AIMS provides an effective **solution for monitoring regenerative changes in landscapes** linked to FFA by ensuring the asset is built or rehabilitated and then maintained over time.

- The potential of using satellite images to **monitor physical changes over large areas through time** is confirmed. These are demanding tasks for field monitors. Instead, satellite images can **provide more objective, quantifiable information over large areas,** (including those of high insecurity that may be off-limits to staff) and **back in time — with reduced financial resources.**

- Satellite optical sensors are able to **single out biophysical variables that human vision cannot**: the near-infrared and shortwave infrared spectral bands can extract more information than our own eyes, which is restricted to a limited interval of visible wavelengths. Radar technology also brings additional detection possibilities (not covered in this study as satellite radar imagery has become globally available only since the end of 2014). In particular, groundwater content, temperature surfaces or vegetation cover health can be easily detected with this type of data.

Image 6. Detection of landscape changes during ‘shock’ years in Maradi, Niger



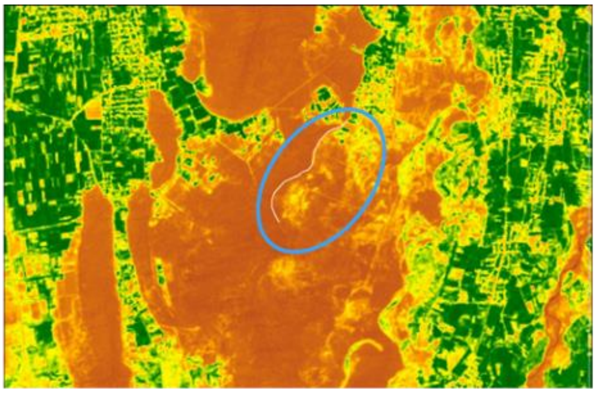
Before the start of the intervention (2015), the areas where FFA was implemented were mostly **not vegetated**, as it can be seen here in 2013 - a good year in terms of climatic conditions.

After the end of the intervention, such as in 2016, despite **dry conditions** during the growing season, those same areas are the ones with the **healthiest vegetation** while the surrounding area has suffered from vegetation loss.

Source: Landsat-8 max-NDVI composites over the growing season (August-September)

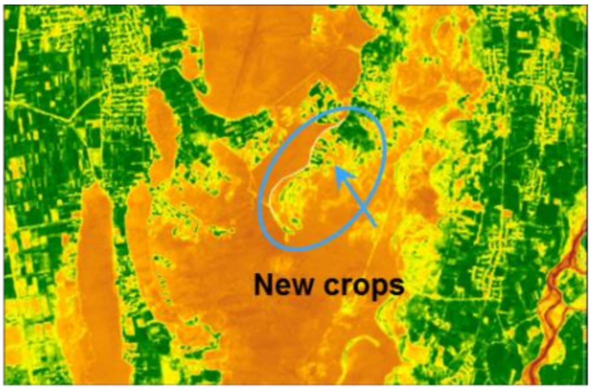
Image 7. NDVI analysis: detection of changes in landscape during 'shock' years along the rehabilitated irrigation canal in Vatan, Tajikistan

Before (2011)



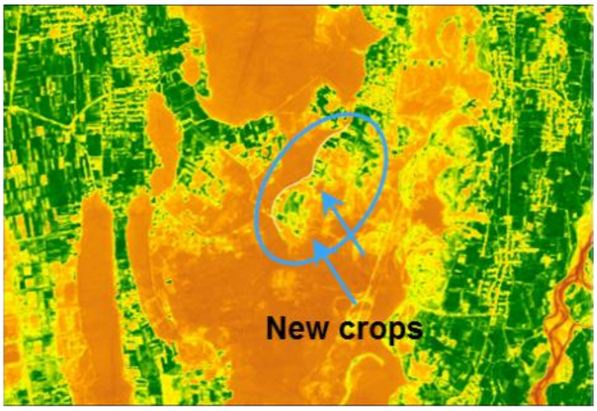
Shock year (drought)

During (2015)



FFA implementation year

After (2016)



Shock year (comparable to 2011)

- Satellite imagery can complement ground-based monitoring with imagery acquired from both before and after the intervention— information that is rarely available from field observations.

- Analyses can focus on 'shock' years more specifically, when applicable after the FFA intervention, and compare the situation with a similar year (in terms of rainfall and NDVI conditions) before the intervention. This enables the evaluation of **how the created or rehabilitated asset has helped communities to better manage climatic events**.

- The long-term analyses in the AIMS project were produced using **widely available EO satellite data** (Modis, Landsat, Sentinel) **and open software** (Google Earth Engine, QGIS), which proved to be a **cost-effective and highly reproducible method**. Further integration of AIMS within WFP programmes evaluation systems is feasible.

Limitations

Nevertheless, satellite imagery does have some limitations and cannot address all the monitoring needs of programme:

- Satellite imagery can detect changes in landscapes, but the additional benefits of FFA initiatives, such as improved household nutrition or other social or economical impacts, cannot be monitored with satellite imagery.

- Some types of FFA activities are not easily traceable from space; in particular, gully control is a complex case that is difficult to assess following a systematic methodology. For this type of intervention, a case-by-case study is recommended, using VHR imagery to follow the progression of the gully— including precise information on the location, size and chronology—to understand its evolution and be able to draw conclusions on whether or not the control initiative has reached its goal.

- Time-specific imagery in some areas of the world is difficult to capture due to cloud cover, resulting in lower availability of satellite imagery. This can challenge the application of the methodology universally.

- Prior to 2013, high-resolution data tends to be less available, making comparisons and analyses difficult for some years in badly-covered areas. This will become less of an issue in the future.

- Very High Resolution (VHR) imagery is mostly only available from commercial providers. However, WFP-VAM is actively developing partnerships and agreements with these providers to ensure convenient and regular access to this essential source of imagery.

AIMS: The Way Forward

AIMS results demonstrate the value of analyzing satellite images to **monitor rehabilitation of degraded landscapes over areas of any size, even areas of high insecurity,** which are the most demanding and difficult for field monitors to capture. Both quantitative and qualitative measures—from satellite data analysis to project follow-up and evaluation of successes—will help determine project success and the long-term impact of various types of implementations.

Additional opportunities for integrating the use of satellite imagery into WFP's existing monitoring tools are also envisioned, such as:

- Better tracking of changes in landscapes induced by FFA activities with a higher frequency;
- Complementing field monitoring activities;
- Developing lessons learned and good practices to better inform future implementations; and
- Providing donors with the evidence base of the success of interventions.

Earth Observation is a reliable and cost-effective tool for off-site monitoring of WFP's FFA and engineering activities. Analysing satellite imagery allows not only qualitative conclusions to facilitate a project follow-up and its successive evaluation, but also historical time series analysis to quantify the long-term impact of various types of implementations.

For more information contact:

Vulnerability Analysis Unit (VAM):
wfp.vaminfo@wfp.org

Asset Creation and Livelihoods Unit:
wfp.assetcreationandlivelihoods@wfp.org

WFP
World Food Programme
wfp.org

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