→ EARTH OBSERVATION SUPPORT FOR THE INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT

Final Report | August 2014

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IFAD is dedicated to eradicating rural poverty in developing countries. Seventy-five per cent of the world's poorest people - 1.4 billion women, children and men - live in rural areas and depend on agriculture and related activities for their livelihoods.

Poor rural people are on the front line of climate change impacts. The ecosystems on which they rely are increasingly degraded, their access to suitable agricultural land is declining, and their forest resources are increasingly restricted. Many are working on marginal rain fed land, with increased water scarcity. In coastal areas, declining fish and marine resources threaten essential sources of income and nutrition.

Poor rural people are dealing every day with this series of complex challenges. They need accurate and consistent information to support strategic planning and to deliver quality solutions to countries around the world.

We are pleased to see the first results of the European Space Agency (ESA) funded pilot projects with IFAD, which demonstrate how Earth Observation (EO) technology can be put to use in the context of IFAD programmes and projects. We appreciate the value of the technical assistance provided by the ESA to the various IFAD project teams – this has helped us begin our navigation of the ever expanding world of satellite information.

We would like to thank ESA for its investment in the five IFAD operations outlined here. We look forward to continuing our cooperation on EO and satellite imagery, particularly with a view on accessing and operationalizing open-source data from ESA satellites (such as Sentinel 2) for project baseline assessments and impact monitoring. We will also be striving to build the EO capacity of IFAD staff, project teams and the government counterparts we work with.

In the future, with regards to the provision of EO-related services in IFAD-supported projects, we envisage a framework which allows us to work with a broad range of partners within and outside Europe, including other Rome-based agencies and partners from the CGIAR system.

The five projects discussed here are concrete examples of how to use a modern tool in the interest of the poor rural communities IFAD works with. The projects in this report supply clear evidence of the advantages of having detailed information for what are seen by many as remote and marginal areas. EO data provides much more than a simple picture from above, it also offers useful insights and specific information for IFAD's work with rural communities.

A particular IFAD programme in which EO will be applied as a key instrument is the Adaptation for Smallholder Agriculture Programme (ASAP), which is the worldwide largest climate change adaptation programme for smallholder farmers. The programme was launched by IFAD in 2012 to channel climate and environmental finance to smallholder farmers. The objective of ASAP is to improve the climate resilience of large-scale rural development programmes and improve the capacity of at least 8 million smallholder farmers to expand their options in a rapidly changing environment.

The use of GIS-EO systems plays a vital part in ASAP, helping us better understand and monitor landscape use in a changing environment.

In the future our needs in the earth observation field will expand as we develop a comprehensive GIS-EO strategy for IFAD. We look forward to continued collaboration in further exploring the use of satellite technology across IFAD projects to eradicate poverty and hunger in rural areas of developing countries.

Kind regards,

Elwyn Grainger-Jones

Director, Environment and Climate Division

International Fund for Agricultural Development

ESA's current and planned technological capabilities place Europe at the forefront of Earth observation. In the next decade, ESA plans to launch more than 25 new Earth observation satellites, which will provide an enormous wealth of new data to be exploited by the scientific as well as operational user communities.

This includes launching the most ambitious operational Earth observation programme in the world: Copernicus (http://copernicus.eu) which will combine data from the world's biggest fleet of Earth observation satellites and from thousands of in situ sensors to provide timely, reliable and operational information services covering land, marine and atmospheric environments and emergency response.

Preparations for adapting to this vast amount of information are in place in Europe for public sector users, but the data will be available globally. The potential for new applications with new user communities in the international development and private sectors is evident.

The multilateral development banks provide support to developing countries to reduce poverty and stimulate economic growth. This involves dealing with the complex challenges of climate change, rapid urbanisation, threats to food security, natural resource depletion and the risk of natural disasters. The provision of accurate and consistent geospatial information is a key component and the world is looking at the development banks to bring the best available datasets to support strategic planning and to deliver quality solutions to the developing countries.

ESA began working in the international development sector through three small-scale technical assistance demonstration projects for the World Bank in 2008. The trials demonstrated the use of Earth observation-based services to support climate change adaptation projects in Belize (coral reefs), Bangladesh (coastal dynamics) and North Africa (land subsidence).

The success of the early pilots resulted in the scaling up of the collaboration with the World Bank in 2010 to include 12 larger-scale activities and the launch of a joint 'Earth Observation for Development', or 'eoworld' initiative (see www.worldbank.org/earthobservation). The 12 activities were spread across the bank's sustainable development network and carried out in over 20 countries in Latin America, Africa, South and East Asia in the following thematic areas: climate change adaptation, disaster risk management, urban development, water resources management, coastal zone management, marine environment management, agriculture and forestry.

In parallel to the World Bank, ESA widened its involvement in the field of international development to include other stakeholders, and as early as 2008 began first collaborations with a strategic player in the domain of agriculture; IFAD. Initially, 3 small-scale activities focussed on Madagascar, but these laid the ground for 5 more substantial demonstration projects that began in 2010, and which are the subject of this report.

These initiatives are being carried out through ESA programmes, together with the European and Canadian Earth observation services industry (mainly small companies) that are in a world-leading position in terms of diversity and maturity of products and services. ESA can therefore be a key partner to international development institutions seeking innovative solutions to address the sustainable development challenge.

The challenge now is to establish a stable connection between existing and upcoming European Earth observation capabilities and the leading institutional players in sustainable development to exploit synergies with funding programmes behind them. The existing partnerships with the multilateral development banks are a start to building a comprehensive approach toward this new user community, taking advantage of ESA's three decades' of experience in developing Earth observation-based applications.

Kind regards,

Volker Liebig

Director, Earth Observation Programmes

European Space Agency

IFAD REQUIREMENTS FOR GEOSPATIAL INFORMATION

The main objective for IFAD is to improve rural food security and nutrition and enable the rural population to overcome poverty and meet the challenges of future climate change. This requires a multi-benefit approach with key components being the improvement of agricultural practices and climate resilience. With agriculture as the key component, some of the challenges faced by IFAD's countries lie within:

- Agriculture and **environment**: community-based watershed protection, monitoring soil degradation, assessment of reduced biodiversity and land use planning
- Agriculture and **water**: optimising water use – assessment of water needs, optimisation of irrigation schemes; managing conflict between different sources of water demand (escalating demands for industrial, urban, and environmental uses)
- Agriculture and **energy**: increasing biofuels cultivation, monitoring of deforestation, land degradation and pollution; monitoring potential conflict with food crops; assessment of potential environmental benefits (GHG emission savings, carbon sinks); development of tools to support subsidies and certification systems
- Agriculture and **climate**: climate-smart agriculture (improve resilience, ensure food security, mitigate climate change by reducing emissions).

Specific requirements for geo-information already identified by IFAD include:

Climate change adaptation and climate risk management, including time series of land cover change, soil moisture, precipitation, river and lake levels and flood risk evolution

Community-based natural resources management; food security; monitoring of crop health and stress

Land-use planning and management including land cover, transport infrastructure, urban land cover change, rural land cover characterisation to assess interplay between rural value-chains and landscapes, coastal erosion/deposition

Monitoring of land degradation and deforestation

Support for the delineation of rural finance instruments (e.g. weather index-based insurance)

EARTH OBSERVATION RESPONSES TO IFAD REQUIREMENTS

The use of satellite mapping services provides many opportunities for the management and verification of the environmental practices associated with agricultural production. EO data are used for planning and assessing land suitability and productivity, and generating land use scenarios to ensure that agricultural practices have no negative effects on the environment.

Through unique EO products, it is possible to map agriculture, land use and environment, distinguish between crops, and crop varieties, planting dates (identify when crops were planted, how they are developing), and detect decreased productivity due to pests, disease or reduction of water. For these reasons, EO is an effective method of collecting information for areas with little ground information.


©IFAD/Nana Kofi Acquah

In many countries, EO data are routinely used to collect statistics on crop yields and production and to monitor the implementation of agricultural policies. As well as monitoring of potential land use conflict, EO data are able to provide an objective control of farmers' declarations with regard to subsidies, concession licenses for energy and cash crops, or conversion of forest to agricultural land. Food security can be addressed by early warning systems using agro-meteorological yield modelling, meteorological conditions, and vulnerability or crop stress reports.

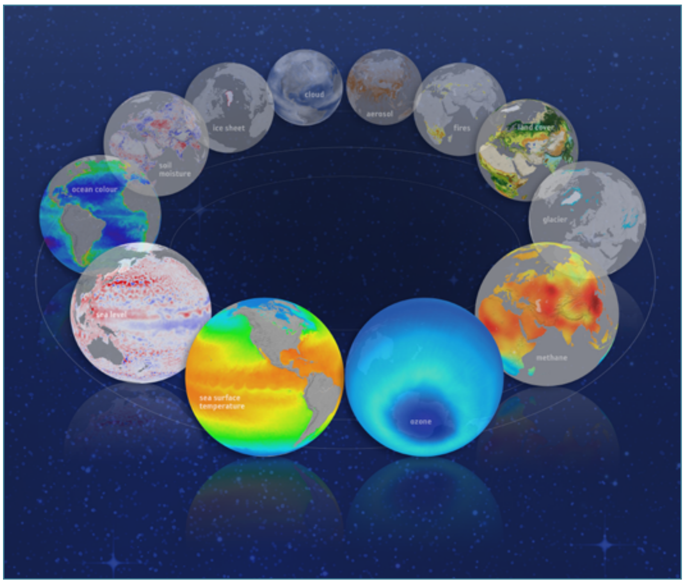
Together with the Agricultural Market Information System (AMIS) collaboration, G20 launched the GEOGLAM (Global agricultural geo-monitoring initiative) to coordinate satellite monitoring observation systems in different regions of the world in order to enhance crop production projections and weather forecasting data. GEOGLAM is intended to provide inputs to AMIS and a full set of specific requirements has already been identified (e.g. cropland area and change, yield estimate, crop acreage statistics, crop production statistics, irrigated crop statistics).

Earth observation is a powerful tool to improve the understanding and management of water resources. This is especially true in regions of the world which lack the ground data to systematically evaluate the status of water bodies or which are unable to develop effective measures to counteract the threat of water scarcity caused by population growth, climate variability, economic development, agriculture production or urbanisation. While increased pollution threatens lakes, rivers, estuaries, and groundwater bodies around the world, EO offers independent, area-wide, standardised, and long-term observations to help address all of these challenges.

EO also plays a critical role in delivering the global and consistent climate data needed to support the climate science and services. The importance of global and sustained EO for monitoring climate from space has long been recognised by the Global Climate Observing System (GCOS), which has defined a set of Essential Climate Variables (ECVs) required to quantify the state of our climate and meet the information needs of the United Nations Framework Convention on Climate Change (UNFCCC). ESA's response to GCOS needs is the Climate Change Initiative (CCI), which is making full use of Europe's EO space assets to generate long-term global records of a set of 13 ECVs.

Long-term climate data sets derived from satellites not only support climate research but also climate services which contribute to decision-making and early warning systems. EO data from the Sentinels will also make a key contribution to the operational climate service in Europe currently developed within the framework of Copernicus at the local, regional and global scale. These include data on Essential Climate Variables (for example the CCI ECVs of Sea Surface Temperature, Sea Surface Height, Sea Ice, Ocean Colour, Land Cover, Aerosol, Clouds, Greenhouse Gases, Ozone, Fire, Glaciers, Ice Sheet, Soil Moisture), Extreme Events (such as floods, drought and storms) and Climate Risk Indicators, combining environmental, socio-economic, and vulnerability information.

EO-based information on ECVs, extreme events, water quality, energy availability, food security, land use/cover, agriculture, coastal subsidence and forest state can also be used to help support climate-proofing and adaptation strategies which require an assessment of the impact and risks of climate change on key infrastructures (e.g. power plants, cities, road network) and resources (e.g. food, water, and ecosystems).



ESA's Climate Change Initiative (CCI) is making full use of Europe's Earth observation space assets to exploit robust long-term global records of essential climate variables, such as greenhouse-gas concentrations, sea-ice extent and thickness, and sea-surface temperature and salinity. www.esa-cci.org

EO INFORMATION SERVICES TRIALS

ESA's work with IFAD started in 2010 with three initial small-scale trial studies in rural regions of Madagascar on land cover use, crop acreage and land tenure.

Although the trials demonstrated the capacity for EO in a regional context, examples of the use of EO information products/services within a wider variety of IFAD projects were required to determine their full potential. An internal IFAD call for projects was carried out in 2012 funded by ESA and subsequently tendered out to European Industry.

The following 5 IFAD projects based on requirements from the IFAD country program managers were completed by European Earth observation Industry over a 10-12 months period and are the subject of this final report.

Land use/land cover and erosion risk in Niger

Land use/land cover and crop type monitoring in the Gambia

Land use/land cover and crop health monitoring in Botswana

Forest monitoring in São Tomé and Príncipe

Historical change monitoring in Vietnam

The trials support the long-term process of mapping and assessing the geospatial needs for IFAD and have opened a dialogue with IFAD on the use of EO and GIS for IFAD interventions as well as for internal use in the organization.

Looking to the future, the upcoming Sentinel series of satellites being developed under Europe's Copernicus programme will continue to provide operational data to organisations like IFAD.

LAND USE/LAND COVER AND EROSION RISK IN NIGER

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Niger is one of the poorest countries in the world where the majority of the rural population still lives below the poverty line. The predominance of crop and livestock farming and poor intra-sector diversification make Niger's economy very vulnerable to climate and market changes. According to IFAD, more than seven million people in Niger are in need of food and the loss in production in pastoral areas caused by the latest food crises in 2010 and 2011/2012 may have long-lasting consequences for the economy and the health and livelihood of the Nigerian population.

EO CONTRIBUTION

Dedicated Land Use/Land Cover information products were produced on both regional and local levels, supplemented by specific information products derived from an enhanced Digital Elevation Model. Information on temporal changes for the period 2007-2012 was provided for six selected communities around the city of Aguié, enabling IFAD to assess the Land Use/Land Cover change within the project area using the specific map products and statistics. A dedicated erosion risk indicator based on these information products has been produced in combination with meteorological data.

The products developed for regional and local level were:

Aguié Local Service (six selected communities around the city of Aguié):

- Land use/land cover map of Aguié with special focus on seasonal agricultural features, derived from recent EO data from two acquisition dates within one season with very high spatial resolution
- Land use/land cover change map of Aguié between 2012 and 2007, derived from recent EO data with very high spatial resolution; change statistics were derived and supplied in addition.

Maradi Regional Service (IFAD project area):

- Land use/land cover map of Maradi, derived from recent EO data with very high spatial resolution
- Digital Elevation Model, derived from EO data
- Slope and Aspect information layer, derived from the produced DEM
- Vector layer with the Basic Drainage System (BDS), derived from the produced DEM
- Erosion Risk Indicator, derived from the produced DEM and Land use/ land cover map

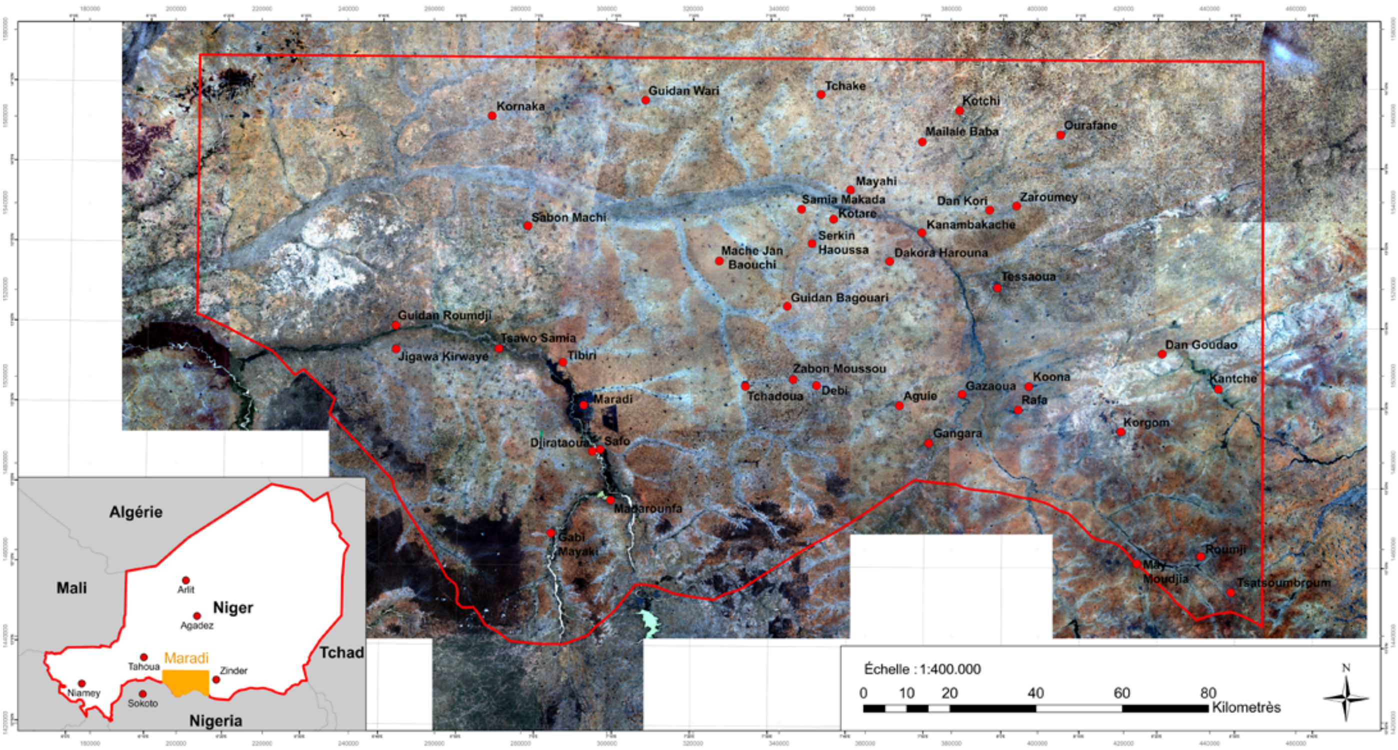


Figure 1: Maradi Regional Service 2013 (Mosaic of RapidEye satellite data with 5 m spatial resolution). Ortho-Image map, produced on basis of VHR optical data.
Credits: GAF AG; Imagery: RapidEye

The common thematic focus of all IFAD activities in Niger is food security and increasing agricultural productivity as well as the income of rural households in order to reduce rural poverty. Since 1980, IFAD has financed eleven projects and programs in Niger, providing about 8.5% of all aid to Niger's rural and agricultural sectors. IFAD focuses its activities in the Maradi region, which covers 3% of the country and comprises 20% of the national population. Located at the southern border of Nigeria, Maradi is the region most affected by the food crises of 2005 and 2010. However, the area is characterised by a high agro-forestry-pastoral and commercial potential and was selected as a priority region by the Government of Niger and IFAD for a number of new IFAD activities over the coming years.

In this context, IFAD voiced the need for geo-spatial information to support both their current and upcoming activities. Earth observation-based products providing both up-to-date and objective information offer a particular value over this partly inaccessible area.

RESULTS

The DEM related products for the Maradi Regional Service revealed the slope information layer indicated gradient values ranging between 1 and 2.5 degrees, providing confirmation that the landscape is predominately flat. The aspect information layer showed that the majority of the slopes face a south-east/southern or western direction.

The Maradi region has a dendritic drainage system, dominated by 2 bigger systems. The dendritic pattern is also an indicator for an area with only marginal slope rates (e.g. a hilly/rolling country), which is confirmed through the produced DEM. Two main river networks can be identified; both networks drain to the west.

The main product within the Maradi Regional Service was an up-to-date Land use/land Cover map of the area, containing sixteen thematic classes. Derived statistics confirm that the Maradi region is characterised as a densely populated area dominated by agriculture. Farming plots are frequent and cover large areas. The land use maps also reveal that irrigation is used for crop farming, but in comparison to other agriculture classes, irrigated land is significantly underrepresented. A few paved roads exist in the area supplemented by dirt roads (laterite roads). Wetlands and water bodies are rare and proportionally small within the region.

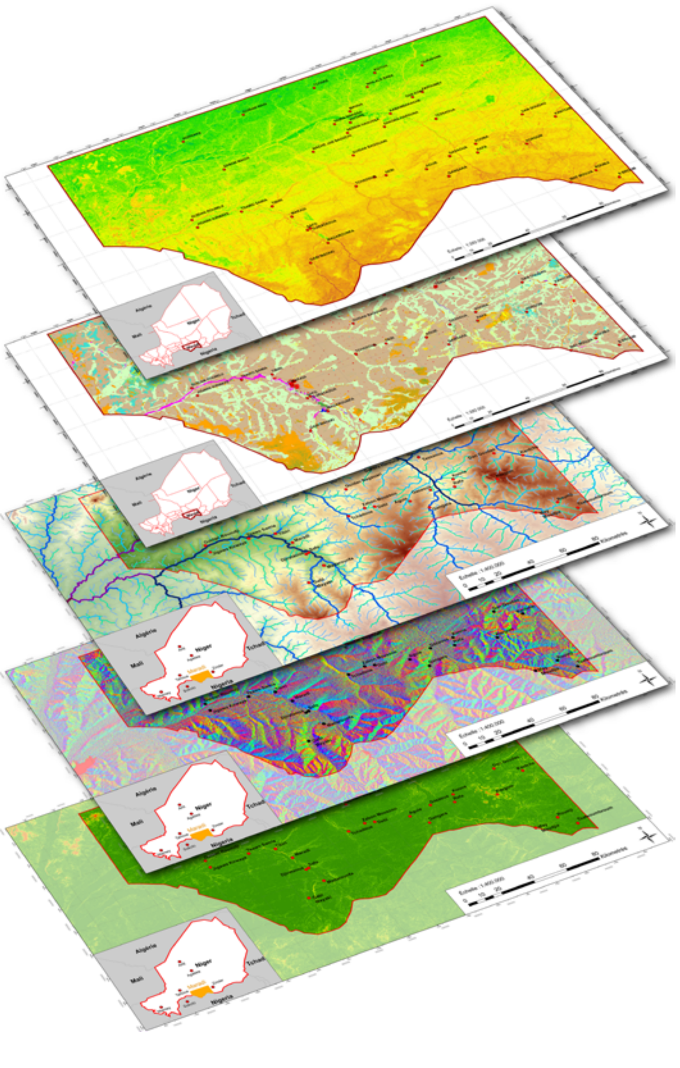


Figure 2: Maradi Regional Service Information. The different information layers derived from the high resolution DEM (Source: ASTER-GDEM, enhanced). From bottom to top: Slope layer, Aspect layer, Basic Drainage System, Land use/land cover map and the final erosion risk indicator.
Credits: GAF AG

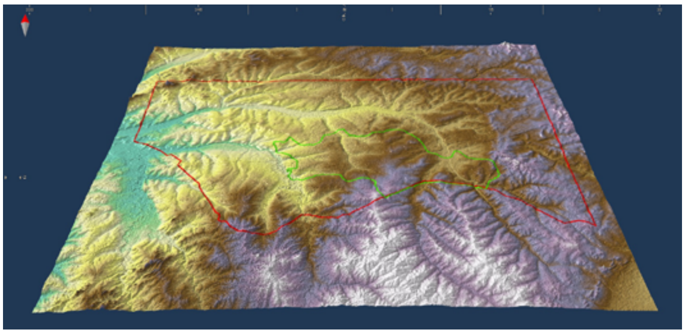
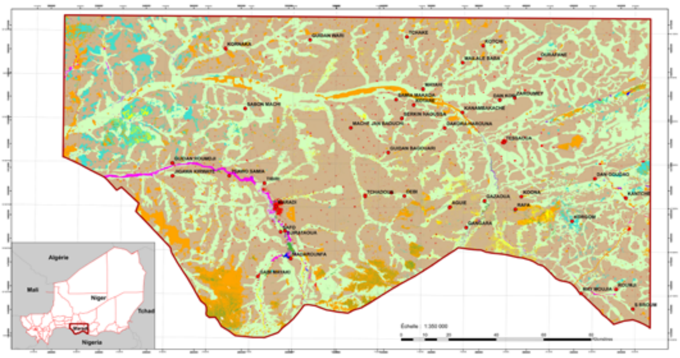


Figure 3: Slightly super-elevated 3D view of the Maradi Regional Service (red) and Aguié Local Service area (Green).
Credits: GAF AG

The final product of the Maradi Regional Service was an erosion risk indicator map, which was derived by a combination of the DEM information layers, the Land use/land cover map and additional in situ data (e.g. meteorological data). The map represented dedicated spatial information about the erosion risk, differentiating between high and low risk areas. The risk of erosion generally increases from north to south of the service area, due to fewer precipitation events with less intensity in the north as compared to the south. At the same time, areas with high slope values increase the risk of erosion, as detected in several smaller Wadis or at plateau rims.

The Aguié Local Service was of particular interest for IFAD and the analysis of changes over the 5-year period between 2007 and 2012 provided important quantitative information. The most important result from the area statistic was that 'Major Agricultural Surface Types' have increased their coverage. The savanna types have been thinned out, which is another sign of the increasing population pressure in the specific region within Niger.



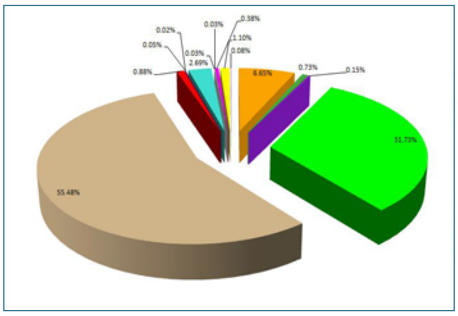


Figure 4: Visualised land use/land cover and statistics of Maradi

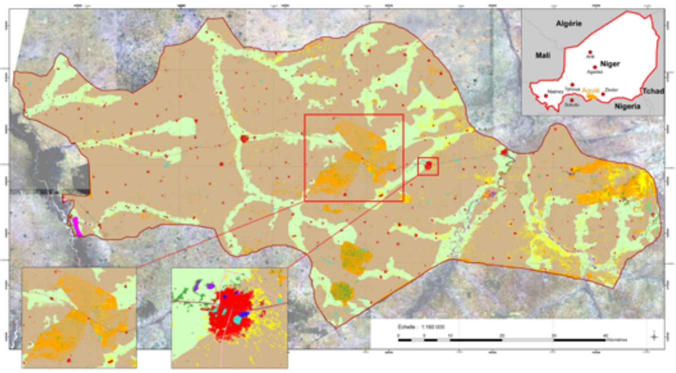


Figure 5: Change Detection Map for the Aguié Local Service (six selected communities around the city of Aguié: Aguié, Djiritawa, Sae-Saboua, Gazaoua, Tchadaoua, Gangara).
Credits: GAF AG

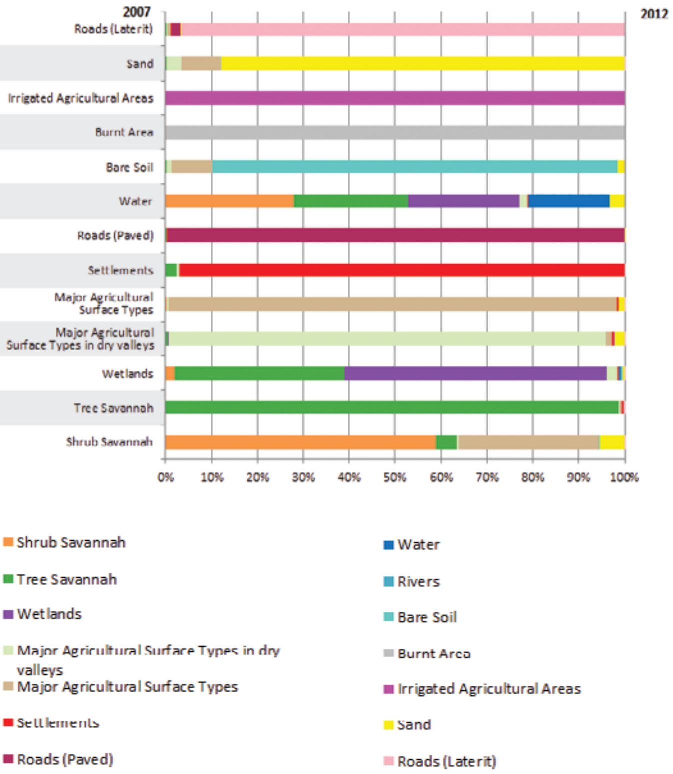


Figure 6: Aguié Local Service - Overview Change Detection Statistics Visual presentation of the Change statistics, illustrating the change for every thematic class from the year 2007 to 2012. The bars represent the overall area for every class in the year 2007. The different colours represent the new thematic class in 2012. For example around 60% of the class Shrub Savannah in 2007 stay in that class but the rest changes into other classes like Tree Savannah, Sand and mainly Major Agricultural Surface Types which highlight the increased agricultural use of the landscape

TRAINING

Given the positive feedback on the products, a dedicated workshop in the country was strongly recommended for future projects/services in the region. To ensure service sustainability, it is important that the local staff members from IFAD in Niger have the technical capacities to work with the products and services, fully and independently. Besides Geographic Information Systems (GIS), the focus of such a capacity training/workshop should also be on EO and EO-derived information products in order to visualise and demonstrate the enormous potential of these products and to support user uptake for the future operation in Niger.

CONCLUSION AND OUTLOOK

This project showed how land use mapping is vital for assessing agricultural and societal practices, enabling improved planning of future projects and project impact assessments. Furthermore, the specialised services on erosion risk can be used to better plan irrigation and climate change adaptation scenarios.

IFAD stressed the efforts needed to handle large data volume and the transfer of the datasets to and within Niger. This underlines the demand for adequate hardware resources and GIS software systems for local IFAD staff in Niger working with the received products. For future product deliveries, data formats with integrated data compression can be considered after consultation with the users.

The limited capacity of the local team to integrate the product into their maps was also an obstacle for using the products in Niger. Perceived value of the Service would be higher if the local stakeholders had adequate capacities to work with the products. For a future project/service in the region, a dedicated workshop in the country is therefore strongly recommended.

At the service utility meeting at IFAD it was also mentioned that the maximum benefit of EO data and products will be achieved through combined application with other data sources in a geographic information system. EO derived information products build an excellent information basis for recent and upcoming project activities, which then should be integrated within a GIS Environment for further analysis. The capacity of GIS analysis, application and data integration is essential for the effective exploitation of EO data and products.

This project was well received in Niger and the results will be used as baseline. Additional mapping using EO in the surrounding regions are foreseen in 2014.

LAND USE/LAND COVER AND EROSION RISK IN NIGER		
Service provider	GAF AG	
Related IFAD project	PPILDA	
Demonstrated potential for IFAD Sectors	natural resource management	land use planning and management

→ LAND USE/LAND COVER AND CROP TYPE MONITORING IN THE GAMBIA

Named after the river that traverses the country from east to west, The Gambia is the smallest nation on mainland Africa. The majority of the population depends on agriculture for its livelihood, but the country's land is constantly subject to soil erosion, degradation and seawater intrusion from the Atlantic Ocean. Irregular rains are also responsible for frequent crop losses.

EO CONTRIBUTION

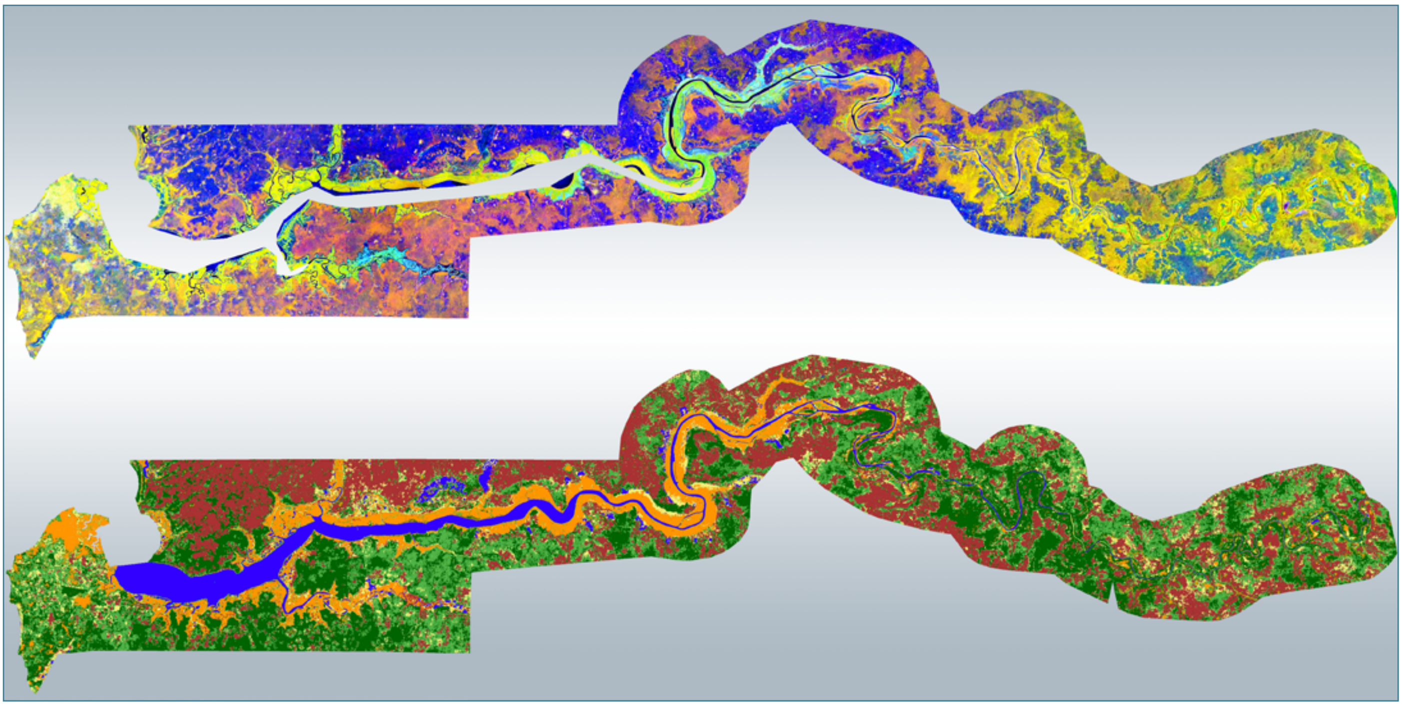
The project establishes a baseline to assess current agricultural practices and document changes from year to year by mapping the whole country using multi-year Synthetic Aperture Radar (SAR) data. These data are acquired from different space borne systems (ENVISAT ASAR, ALOS PALSAR-1, and Cosmo-SkyMed) complemented by optical medium resolution data MODIS.

The availability of seasonal and annual remote sensing data is of high importance for land cover and change maps with particular emphasis on agriculture. Today, the only operational sensors fitting these stringent requirements are the so-called low and medium resolution sensors, which acquire data on a daily basis at spatial resolutions ranging from 1000 (low) to 250 (medium) metres. High resolution (10 to 30 m) to very high (lower than 10 m) spaceborne sensors, unfortunately, do not have systematic acquisitions, hence limiting the analysis in temporal and spatial terms.

The method exploited in the Gambia Project reflects the above mentioned considerations, leading to the following products:

1. Multi-year high resolution (15 metre) ENVISAT ASAR Alternating Polarization (HH/HV) and ALOS PALSAR-1 Fine Beam Dual (HH/HV) data acquired before 2013 contribute to a national baseline land cover map providing the status quo prior to this year.
2. Daily acquired MODIS 250 metre data from 2002 to 2012 are selected to produce, countrywide, 16 days Vegetation Productivity Index maps over the agricultural area identified in the baseline map.
3. During the 2013 crop season, Cosmo-SkyMed Stripmap 3 metre data were regularly acquired for a selected area, leading to a detailed land cover map, which also includes the differentiation between rice and other crop types.

Figure 1: The Gambia at 15 m resolution based on multi-year ALOS PALSAR-1 and ENVISAT ASAR data (top) and derived land cover map (bottom). Classes: agricultural area (brown), Mangrove & Sandbanks (orange), water (blue), bare soil (light yellow), vegetation-medium biomass (light green), vegetation-strong biomass (dark green).



Under the Participatory Integrated Watershed-Management Project (PIWAMP) and the National Agricultural Land and Water Management Development Project (Nema), projects, IFAD and the Gambian Government are jointly focusing on poor rural communities and their participation in local development, as well improving agricultural production while safeguarding the environment.

Particular effort is put into helping the people in the lowlands (close to the river Gambia) to achieve a sustainable increase in the production of rice, the country's main staple food.

RESULTS

The use of the existing ENVISAT ASAR and ALOS PALSAR-1 archive data provides a valuable data source, allowing the generation of a consistent national baseline map, as shown in Figure 1. The level of detail in this land cover map can be enhanced by systematically acquiring seasonal time-series images at higher spatial resolution, as shown in Figure 2. In addition to the baseline map, this product also offers the possibility to monitor and quantify the vegetation growth along the whole crop season as well as to differentiate the main crop types. By exploiting medium resolution data acquired on a daily basis, the baseline map provides information useful to derive and analyse area and productivity changes during a given period. An example is illustrated in Figure 3, using time series data to show the comparison of agricultural changes taking over a given period.

The project provided IFAD with the objective measurements needed to support effective decision-making and policy dialogue.

> "One of the most important results of this initiative is that it gives us hard evidence that we can use in policy dialogue with the government and other donors. This helps us mobilise more resources to invest in smallholder agriculture, thus boosting economic growth that is sustainable and inclusive."

Ides de Willebois, Director of IFAD's West and Central Africa Division

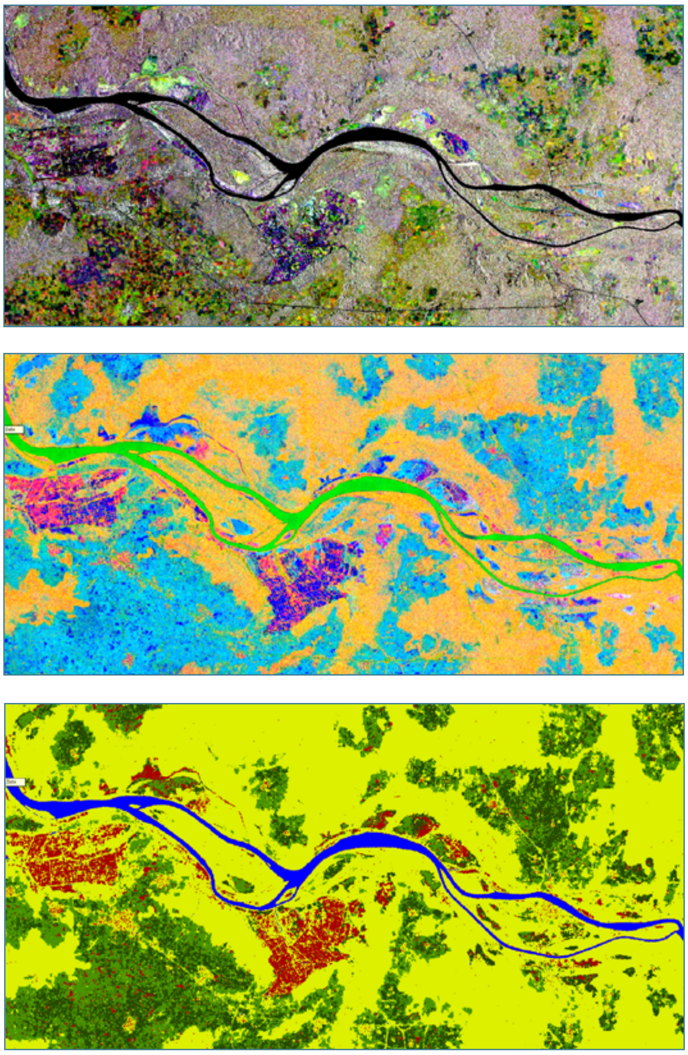


Figure 2: Detail of The Gambia at 3m resolution based on seasonal Cosmo-SkyMed SAR data acquired in 2013 (top); Seasonal evolution: in blue and red crop growth (middle); Land cover map (bottom) - classes: rice (brown), crop type 1 (dark green), crop type 2 (light green), water (blue), forest (yellow).

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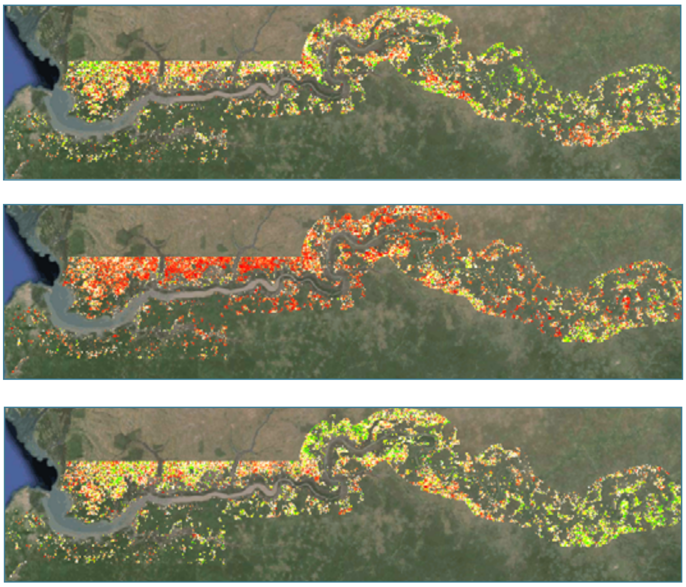

Figure 3: Vegetation Productivity Index of the agricultural area relative to mid of September (expected peak of crop season) 2010 (top), 2011 (middle), 2012 (bottom) of The Gambia (250m resolution).

TRAINING

In October 2013, IFAD in collaboration with the European Space Agency (ESA) and SARMAP, organised a five-day training workshop in Banjul on the use of spaceborne Earth observation (EO) data for agricultural purposes. 32 participants were drawn from government departments, such as Agriculture, Forestry, National Environment Agency (NEA), and the private sector. The training course combined both theory and practical sessions. A one-day field visit to Jarumeh Koto in Central River Region North (CRR/N) was carried out to understand and appreciate the usefulness of the maps generated from EO data.

The training course supported capacity building/knowledge transfer in the region and beyond, as well as an appreciation of the benefits for planning, monitoring and evaluation (M&E) and investment decision making.

The government and other participants are asking for more in-country capacity building and IFAD is currently addressing how best to follow up after the ESA trial. As a result of the workshop, 22 participants have formed the Gambia Earth Observation Network (GEON).

Participants to the 5 day training workshop on the application of spaceborne Earth Observation (EO) for agricultural purposes, October 2013. Credits: Abdourahman Sallah.

Demonstrating field validation of GPS-enabled devices to some of the workshop participants during a field visit to Jarumeh Koto rice field in Central River Region North.
Credits: Moses Abukari.

CONCLUSION AND OUTLOOK

This project used radar satellites to carry out crop baseline mapping and crop health assessment as a consistent national baseline. It was successful in convincing both the Country Project Manager and the Gambia government of the usefulness of EO information. It has led to the establishment of the GEON (Gambia Earth Observation Network) and further work in the region using Earth observation is expected.

The delivered products were used by both IFAD (chiefly as input into the design of a new project on Climate Change-ASAP in the Gambia) and the Government of Gambia to serve as national reference map for land use map or baseline map on land cover map in the country.

“Using these products to engage in policy dialogue cannot be foreseen explicitly but flexibility and availability of quality products that can be adapted makes sharing of such national important data with key decision and policy makers very critical to influence their perception and understanding of urgent action needed to address key challenges.”

Moses Abukari, Country Project Manager Gambia

Given the success of this project and the provision of reliable access to the data and information, it is now IFAD's intention to use the immediate output/products to feed into future planning of interventions in the country. This could be realised through Adaptation for Smallholders Agricultural Programme (ASAP) contracts and by establishing a partnership with the GEON for enhanced capacity building. In time, this should lead to the EO services being fully integrated into development operations from planning to evaluation, requiring the continuous services of the industry.

LAND USE/LAND COVER AND CROP TYPE MONITORING IN THE GAMBIA	
Service provider	Sarmap
Related IFAD project	Integrated Watershed-Management Project (PIWAMP) and the National Agricultural Land and Water Management Development Project (Nema)
Potential for IFAD Sectors	natural resource management; land use planning and management

LAND USE/LAND COVER AND CROP HEALTH MONITORING IN BOTSWANA

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Botswana is a livestock country with the majority of land use comprising semi-arid rangeland. However, arable farming is also a predominant practice among smallholder farmers. Despite the large increase in cultivated area during last decade, Botswana has one of the lowest crop yields in sub-Saharan countries and remains dependent on imports for the great majority of its food grain requirements.

The total area planted to field crops is only around 0.2% of the total land area. Yields are very low and usually only contributing 10-15% of annual food grain needs.

EO CONTRIBUTION

Earth observation-based products/services represent a particularly efficient method to map distribution of agriculture areas, livestock forage, ground water and soil degradation to monitor crops and external impact over crops and productivity.

Service 1 of the Botswana Project (Land use/land cover - LULC) explores the EO capabilities in the production and update of high quality land use and land cover maps. DEIMOS-1 (22 m) and Landsat TM (30 m) images were used to ensure the specified accuracy and a good spatial and temporal coverage. The spatial resolution and the large amount of accessible EO data increase the probability of high quality cloud-free images. Service 1 is defined to produce:

- LULC status map for 2011 for Gumare, Parakarungu, Tonota, Sefhare, Jwaneng, Mmathethe and for 2013 for Parakarungu, based on DEIMOS-1, and for 2006 for Tonota using Landsat TM;
- LULC change map for Tonota and Parakarungu, computed from LULC maps produced for the two different time periods;

Using EO, it is possible to verify the trends in land use/land cover as well as the effectiveness of measures implemented by IFAD and The Botswana Ministry of Agriculture (MOA).

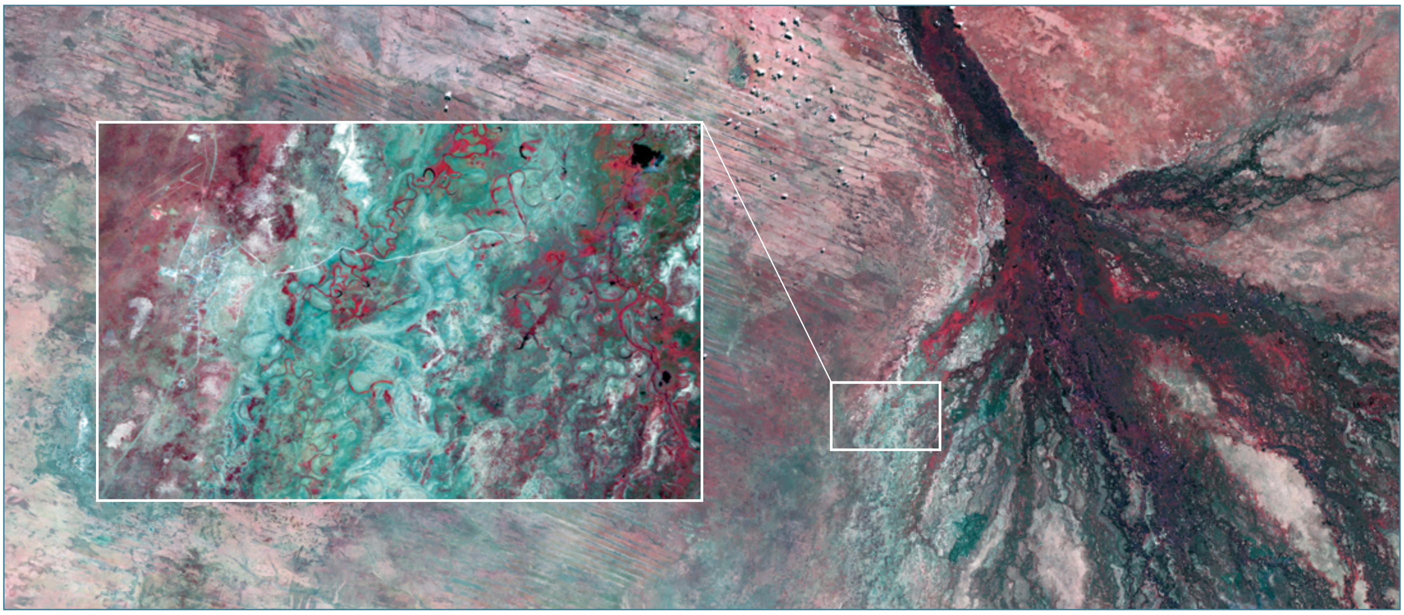
Service 2 (Crop Health Monitoring - CHM) takes advantage of EO capabilities in the generation of multitemporal maps useful for crop and vegetation status monitoring. Based on Normalised Difference Vegetation Index (NDVI) values, both DEIMOS-1 (22 m) and MODIS (250 m) satellite imagery were used. Service 2 delivered the following products for all the defined areas of interest (Gumare, Parakarungu, Tonota, Sefhare, Jwaneng, Mmathethe) from 2010 to 2013 based on the available imagery:

- Current crop status (NDVI)
- Crop status short term evolution (NDVIchg)
- Crop season status from the start of the season (NDVIaccum)
- Crop season maximum status during the season (NDVImax)
- Crop temporal heterogeneity within the season (NDVIheter)

During 2013, an Early Warning Service was carried out over the Parakarungu region for crop monitoring, delivering CHM products and reports on a monthly basis with near real time information of the status and the evolution observed with DEIMOS-1 imagery. CHM's early warning service supports disaster monitoring and evaluation in case of plagues or diseases affecting the vegetation or some specific crops.

Crop Health Monitoring products contain critical information on the vegetation status and its temporal evolution, providing IFAD and GoB with both a reference and updated information of the evolution of the crops and the vegetation.

DEIMOS-1 image of the Okavango Delta in northern Botswana, with zoom over Gumare.
Credits: Elecnor Deimos Imaging 2014



Food security is largely underpinned by imports financed by mineral exports. Dry years and droughts pose a threat to household food security in rural areas although national food security is always guaranteed by the ability to import staple foods. However, the government plans to reduce the country's high dependence on food imports.

Despite robust economic growth, rural communities in Botswana remain plagued by high levels of poverty and unemployment, whilst urban populations have become increasingly prosperous.

The Government of Botswana (GoB) has therefore been seeking IFAD support in tackling the problems of chronic rural poverty, low agricultural productivity and heavy dependence on food imports. Together with the GoB, IFAD has established the Agricultural Services Support Project (ASSP) aiming to contribute to economic diversification, reduction of rural poverty and food insecurity, and improved livelihoods of rural communities. The specific development objective is to achieve a viable and sustainable smallholder agricultural sector based on farming as a business and not reliant on subsidies or welfare measures.

RESULTS

Service 1: Land use/Land cover

The Land use/land cover map results highlighted in Figure 1 is for the area of Sefare (2011). These maps are used to identify the most critical land use classes such as forests, agriculture, arable, savanna and shrub land, bare soil, sand, plains and rocks, water bodies, wetlands, artificial areas and burnt areas. By overlaying this set of information with other ancillary data in a GIS software, users are able to monitor potential risks of desertification of agriculture areas or even the loss of useful soil. EO techniques are used as a thematic and geometric reference for the production of further maps for change detection and spatial analysis of the region. The results indicated the predominance of shrub land, savanna and arable fields in the area. Near the margins of Limpopo river, in South Africa, some areas identified as bare soil during dry season were later identified as agriculture areas, due to the existence of irrigated fields. Road connections are visible in red over all of the territory around the main arable areas.

Figures 2 provides an overview of changes in arable/agricultural areas, showing gains, losses and no changes ('maintain'). Figure 3 provides the evolution of land cover for more detailed classes of information. This information shows that there was no major land use and cover change between 2006 and 2011. However, the area covered by agriculture and arable fields decreased in 5 years and the urban areas (e.g. Tonota or Francistown) are expanding. Nevertheless, shrub land and savannah areas, which may be used as pasture for cattle, are still dominating the area.

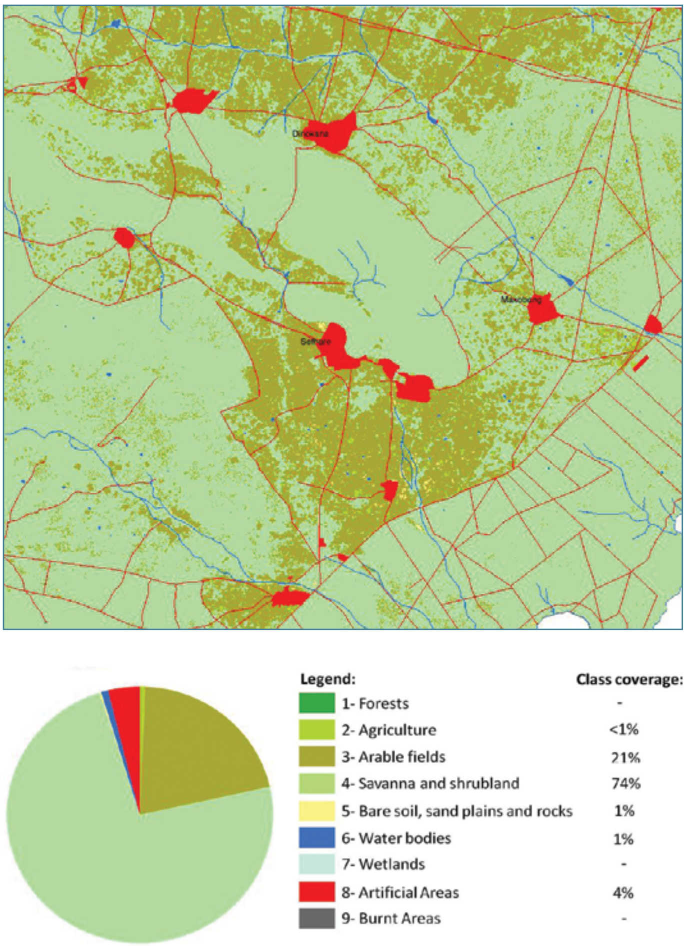


Figure 1: Land use/Land cover- ASC5 Sefhare (2011)

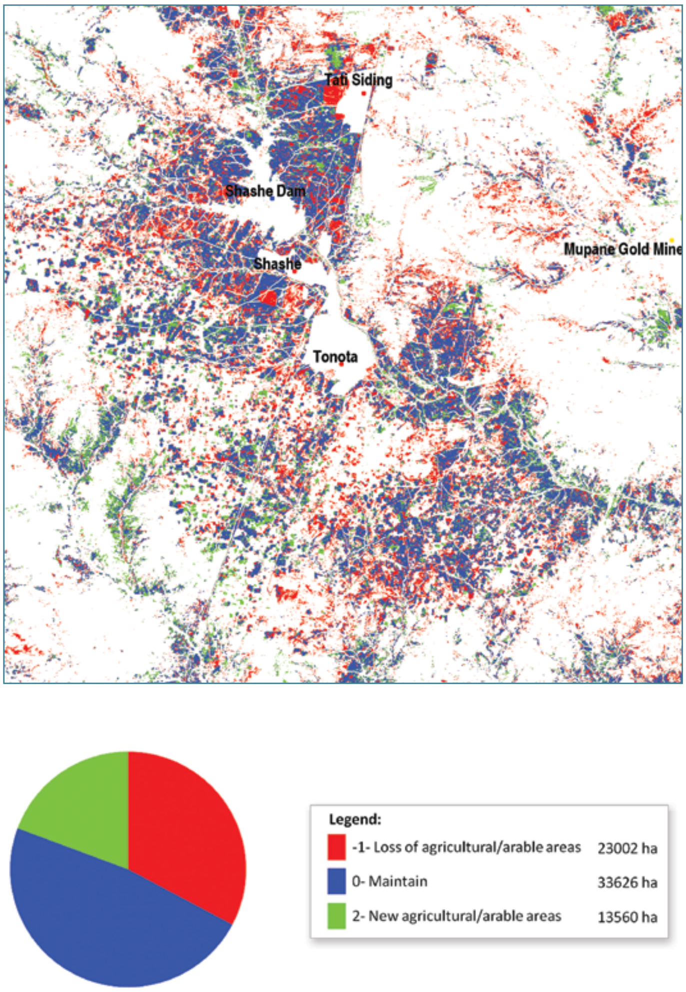


Figure 2: Land cover change map extracted for Tonota (2006-2011)

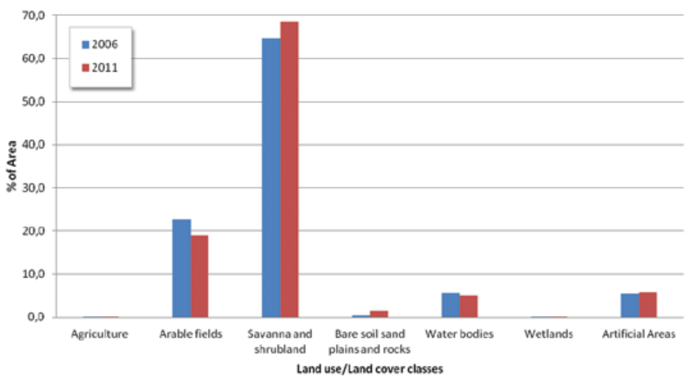


Figure 3: Temporal variation of area covered by each land use/ cover class, ASC4- Tonota (2006-2011)

Service 2: Crop Health Monitoring

Considering the whole set of CHM products, a complete analysis of the evolution of the vegetation is available from different perspectives. While NDVI maps show how the crop is performing now, NDVIchg maps illustrate which is the crop trend in the last period. NDVIaccum maps give an indication of crops growth in the current season with respect to other seasons, and NDVImax maps provide visibility on where and when the crops have achieved maximum growth status. Finally, NDVIheter show those regions that have significant spatial variation in the crop status allowing the possibility of deriving single or double cropping.

By displaying and analysing the evolution observed in the vegetation status over a period of time, CHM maps allow users to compare the evolution from different dates and analyse the impacts of crop incentives or even land planning policies for each of the covered areas. CHM maps have also been used as an indicator for the impact of climatic events, such as droughts or floods, over the crops and its surroundings, complementing other sources of ancillary information.

CHM products have been delivered in several formats, including a report with comments and brief interpretation of the observed trends over the studied regions. Figure 4 shows evolution for year 2010 and 2012 of MODIS based CHM products (i.e. Crop status, NDVI, over ASC13 Jwaneng on year 2010 and 2012).

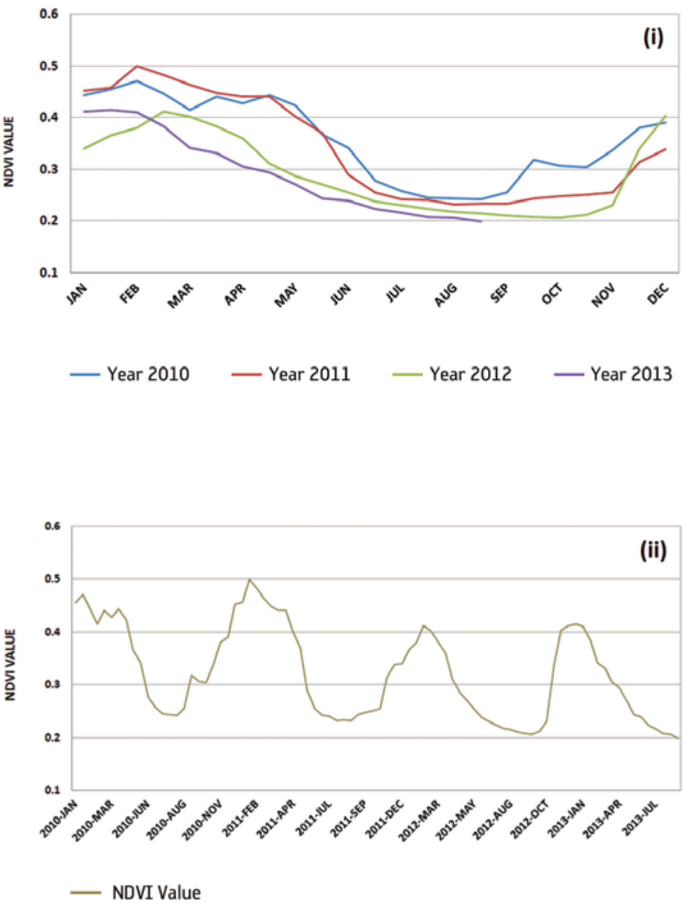


Figure 4: Example of multi-year analysis of MODIS-based CHM product (Crop status, NDVI, over ASC13 Jwaneng). Graphic (i) represents the evolution of NDVI from January to December on each year whereas the same NDVI evolution along the 2010-2013 period is displayed in (ii)

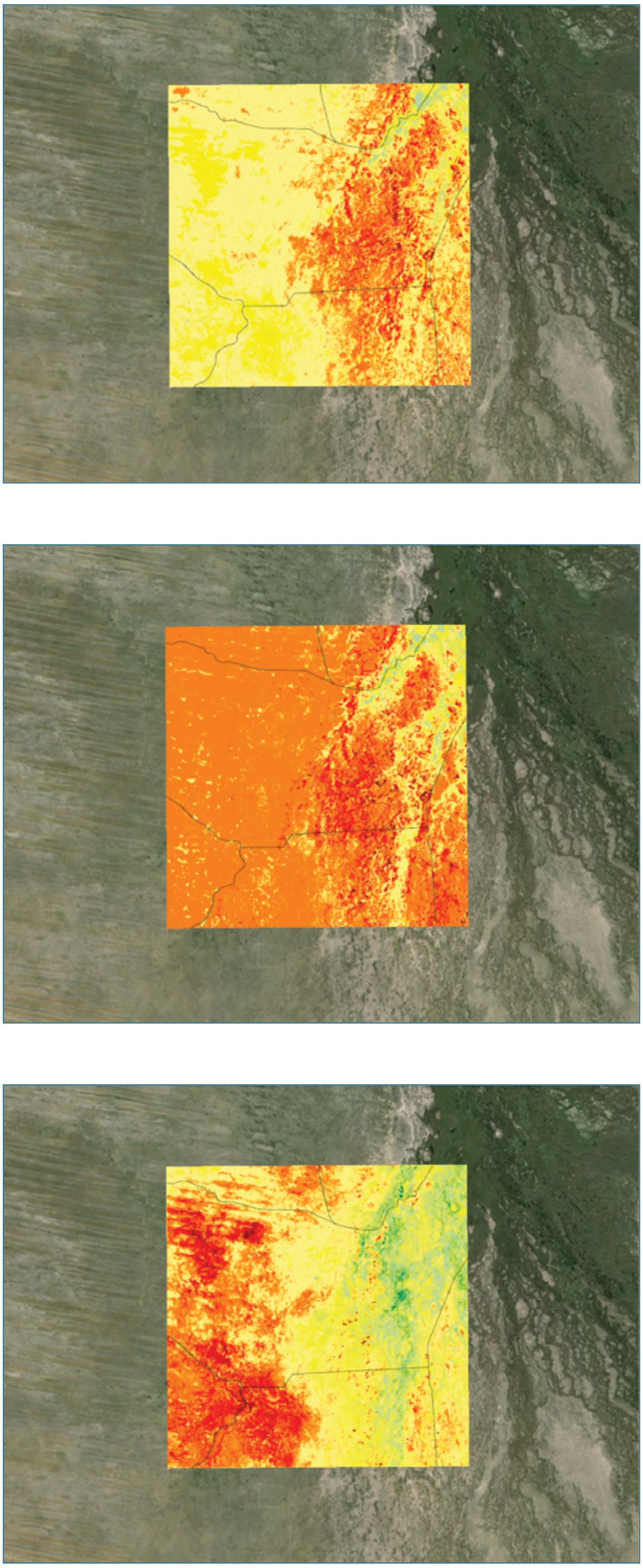


Figure 5: DEIMOS-1 CHM products (Crop status in May and June 2011 and short term evolution, NDVIchg, over ASC1 Gumare).

A detailed review of individual crop status (NDVI) products over time (as shown in Figure 6) has been included in the reports. A decrease of vegetation driven by a severe drought over the region is noticeable (in red).

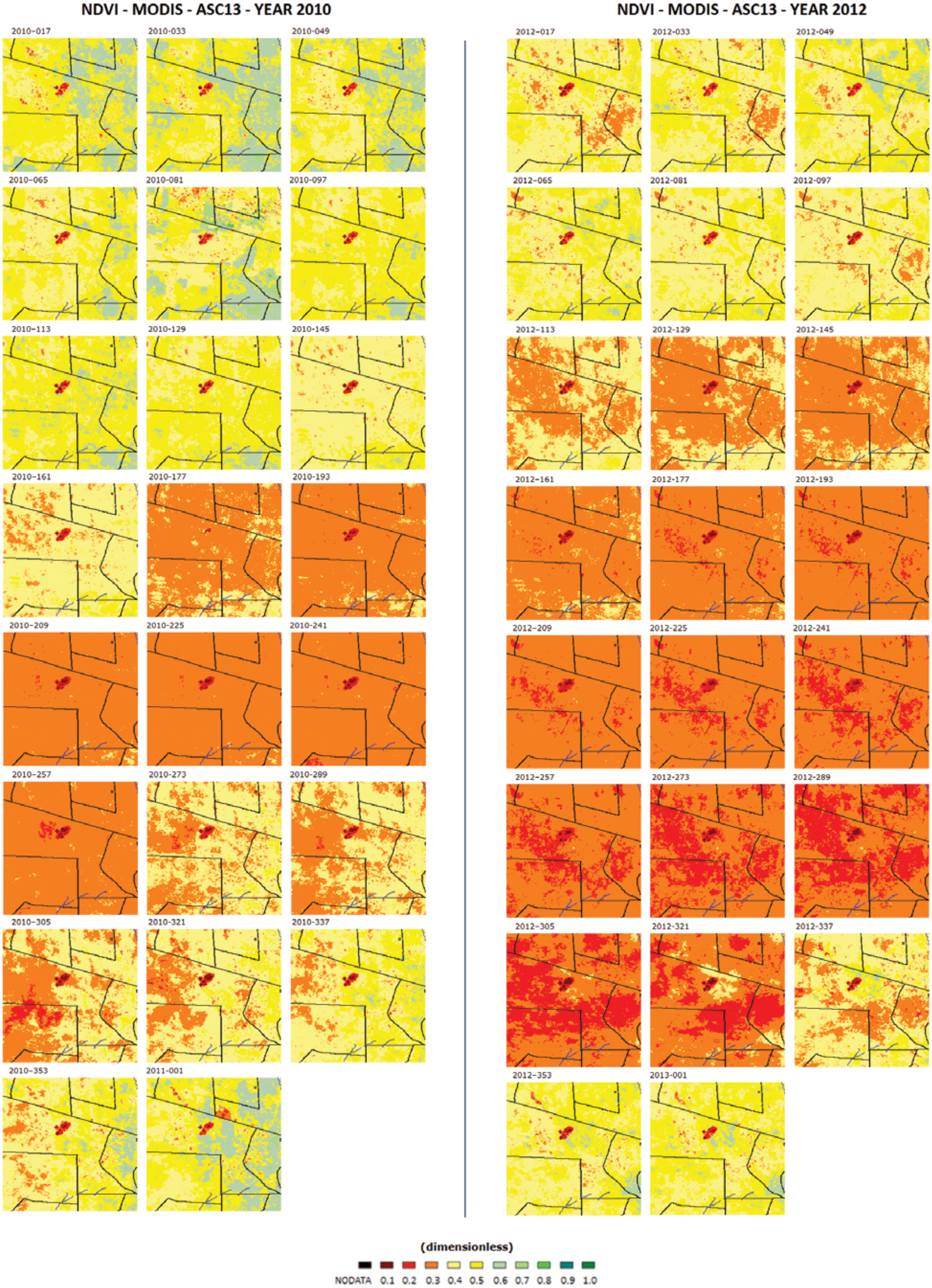


Figure 6: Overview of the evolution for year 2010 and 2012 of MODIS-based CHM products (i.e. Crop status, NDVI, over ASC13 Jwaneng on year 2010 and 2012).

TRAINING

The uptake of the EO products by the local users (the Botswana Government) and their capacity and ability to use the EO information was hampered by the lack of field campaign or training in this project. The test sites were spread all over Botswana meaning that a dedicated field campaign with visits to local sites was not economically viable during this project.

Therefore, further work is needed to ensure that these EO products are fully used. Local user understanding of these services is essential to fully benefit from the products. Dedicated future EO services proposed by IFAD would need to integrate local capacity and understanding of the services into the project designs.

ERS SAR multitemporal image of Botswana

Credits: ESA

CONCLUSION AND OUTLOOK

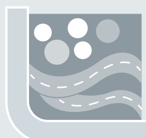
This project aimed to support IFAD in their ASSP activities for the benefit the Government of Botswana and local authorities. This was done by producing updated land use/land cover (LULC) maps and by providing input to crop productivity monitoring for rain fed field crops as well as monitoring impacts of irrigation and natural climate cycles on crops.

After completion of the EO services the IFAD team in Rome and in Botswana initiated a review process to assess the impact, benefits and limitations of the delivered EO products. Feedback was provided in a dedicated user's utility questionnaire. In addition, the Ministry of Agriculture in Botswana was also contacted to gather the products' assessment from local users.

The IFAD team in Rome acknowledged that LULC service's products contributed toward achieving the objectives of IFAD activities in Botswana and notes: "LULC could be used as a baseline for impact evaluation during the project life and after completion".

The EO products produced were intended for the use of the local user and the Botswana Government - however further work is required to meet this objective.

Furthermore local capacity building and training should be a high priority to ensure long term uptake of products to support government activity for sustainable land use practice.

LAND USE/LAND COVER AND CROP TYPE MONITORING IN THE GAMBIA	
Service provider Botswana	Deimos
Related IFAD project	Participatory Smallholder Agriculture and Artisanal Fisheries Development Programme (PAPAFPA)
Potential for IFAD Sectors	 natural resource management  land use planning and management

→ FOREST MAPPING IN SÃO TOMÉ

© IFAD /Susan Beccio

The natural rain forest - Obo National Park - of São Tomé is a pristine environment with a high ecosystems value. Covering about 40% of the country's surface, it includes examples of all the different biotopes: the lowland and mountain forests, mangroves and a savanna area. The protected area of the Obo National Park (Parque Natural Ôbo de São Tomé e Príncipe), divided in a core and a buffer zone, was created on both São Tomé and Príncipe islands to protect the country unique natural heritage. The past years it has experienced a rapid degradation due to illegal logging and natural climate change.

EO CONTRIBUTION

On the African island nation of São Tomé and Príncipe, the biologically diverse rainforest in Obo National Park is under threat from illegal logging. To support IFAD and the local government's monitoring of logging activities and deforestation, yearly maps of forest cover, types, clear cuts and deforestation are being produced. This service trial supports the overall IFAD project aim to implement more efficient practices in the rural sector.

Spaceborne assets can help to reduce the extent and cost of large-scale field surveys and identify hot spots for further investigation on the ground.

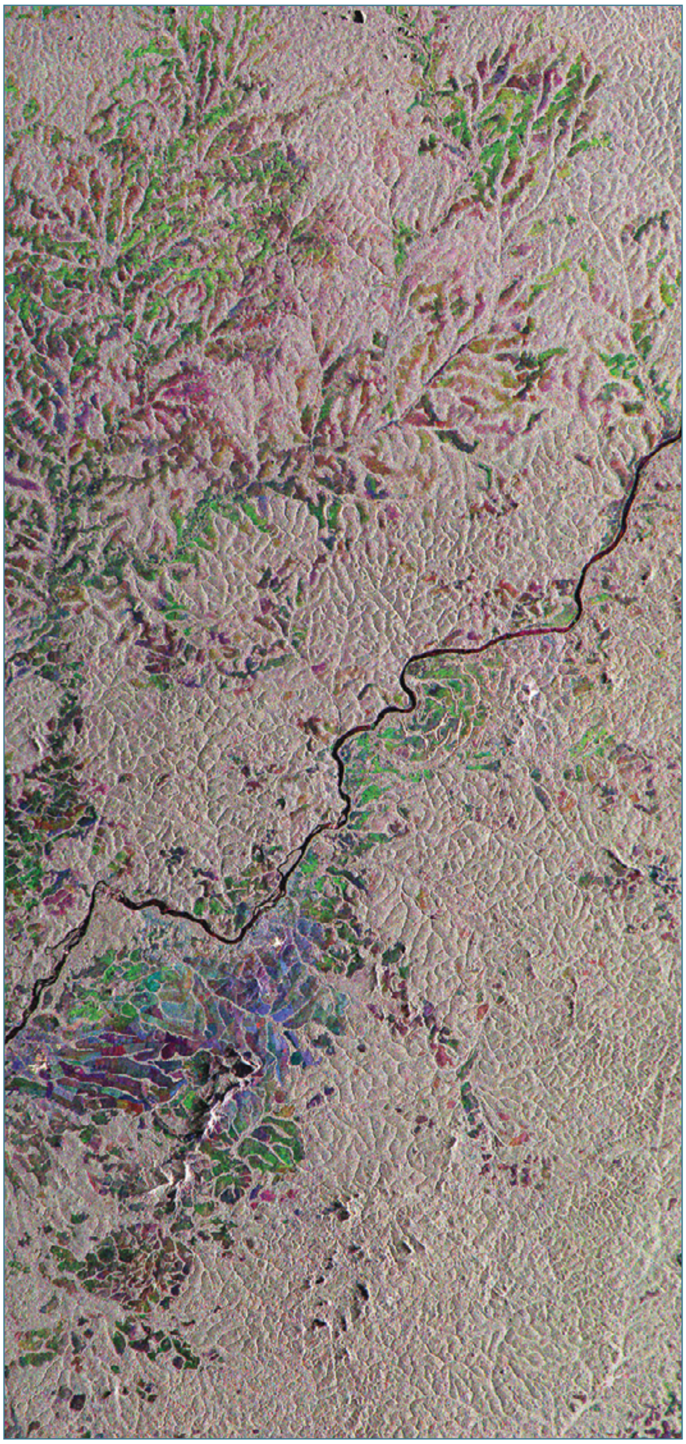
EO satellite data provides a cost-effective means of achieving inventories of forest cover and deforestation/clear cut areas across hundreds of square kilometres and for multiple points in time. It is able to provide a consistent and timely data and information source, even in remote areas, which are difficult to access.

The current activity delivers a self-contained demonstration for forest monitoring as critical input for IFAD/PAPAFPA and the complementary project of the Global Environment Facility (GEF) and IFAD.

As of today, no consistent and accurate in situ information on status and change of forest cover, types and clear cuts as well as deforestation areas is available.

Thus the EO contribution to this project is focusing on:

- A highly detailed forest cover and primary forest types inventory for the 2011 baseline year
- Yearly change mapping of forest clear cuts and deforestation starting 2009 to most recent
- A precise Digital Terrain Elevation model



An example image shows deforestation in Cameroon in red (2008) while the areas in green and blue are the areas where deforestation started in 1994.
Long-term datasets of satellite data are very useful in ongoing studies, particularly in the field of Change Detection - such as deforestation. They can be combined into one "multi-temporal" image that highlights the changes in a location over a period of time.
Credits: ESA

The objective of the São Tomé forest monitoring project is to support IFAD and the Government of São Tomé to implement a sustainable satellite-based monitoring scheme for tracking deforestation and illegal logging.

The results will contribute to the Participatory Smallholder Agriculture and Artisanal Fisheries Development Programme (PAPAFPA) in São Tomé and Príncipe funded by IFAD[1], AFD[2] & MAE[3].

The aim of PAPAFPA is to develop the agricultural and fisheries sector and to improve the country infrastructure without damaging the rich natural reserves of the islands. Additionally the results will contribute to a complementary project of the Global Environment Facility (GEF) and IFAD, which aims at promoting biodiversity mainstreaming and integrated ecosystem management in the buffer zones of Obo and Principe Natural Parks and to increase income generation through biodiversity-friendly production and sustainable business.

[1] www.ifad.org/operations/projects/design/100/sao.pdf – [2] Agence Française de Développement – [3] French Ministry of Foreign Affairs

RESULTS

Forest cover and primary forest types inventory 2011

High Resolution (HR) to Very High Resolution (VHR) images from different satellite platforms acquired during 2011 have been employed to produce the most precise forest inventory available today, reaching a 0.01 ha (=100 m²) minimum mapping unit. Based on a combination of optical data from WorldView-2 (0.5 m) and radar data from Radarsat-2 (10 m), forest coverage and main forest types were mapped. Inclusion of radar sensors allows forest mapping also for tropical inland areas with usually frequent cloud coverage. This resulted in a homogenous forest inventory for the whole Obo National Park of São Tomé for the year 2011. Both the core national park area as well as its buffer zone was covered. Figure 1 shows an example of the mapped 2011 forest cover and primary forest types inventory.

Statistical analysis shows the predominance of forest cover in 2011 with more than 92% of the complete project area (681.96 km²), over 95% of the Obo National Park (ONP) buffer zone (207.96 km²) and more than 98% of the ONP core zone (248.64 km²).

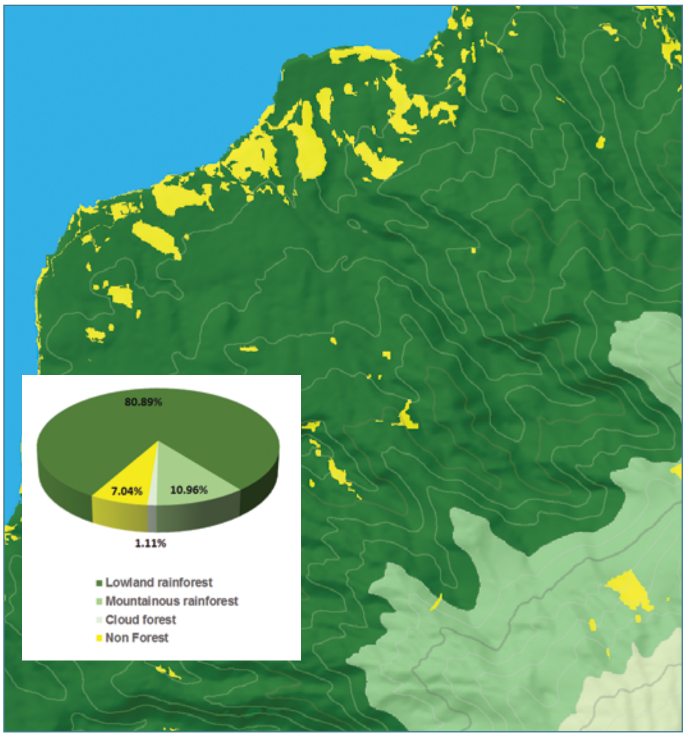


Figure 1: Forest cover and primary forest types inventory 2011 map

Forest clear cuts and deforestation yearly mapping starting 2009 to most recent:

Historic and recent satellite images from a variety of optical and radar sensors were utilised to produce a multi-temporal inventory of forest clear cuts and deforestation areas for 2009, 2010 and 2012/2013 dates. Due to the large heterogeneity of the satellite data involved, resolution of the change maps is at 0.09 ha (=900 m²) minimum mapping unit. Based on a time series of optical data from KOMPSAT (1 m), Formosat-2 (2 m), RapidEye (5 m) and radar data from TerraSAR-X (3 m) and Radarsat-2 (10 m), forest clear cuts and deforestation areas were consistently mapped (one map for 2009, 2010 and 2012/13 each).

Hotspots of deforestation (Figure 2) were identified around Porto Alegre (southwest), Dona Augusta (south - oil palm plantation), Monte Café

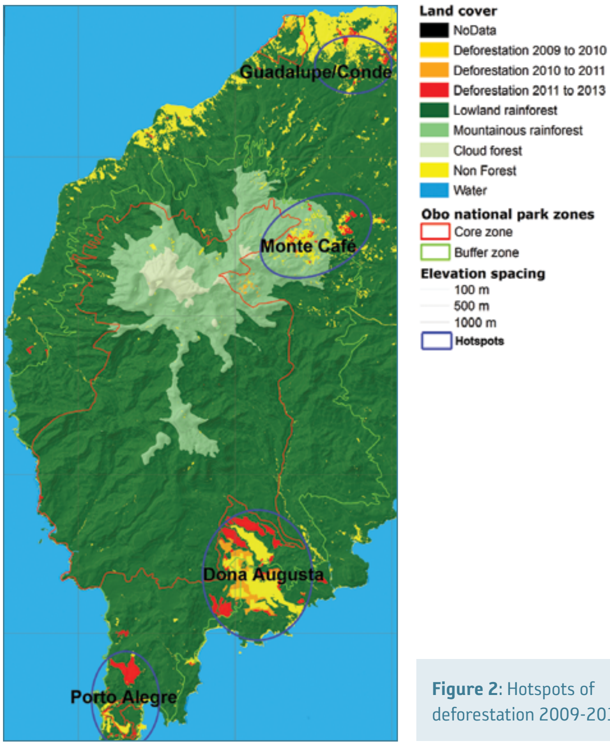


Figure 2: Hotspots of deforestation 2009-2013

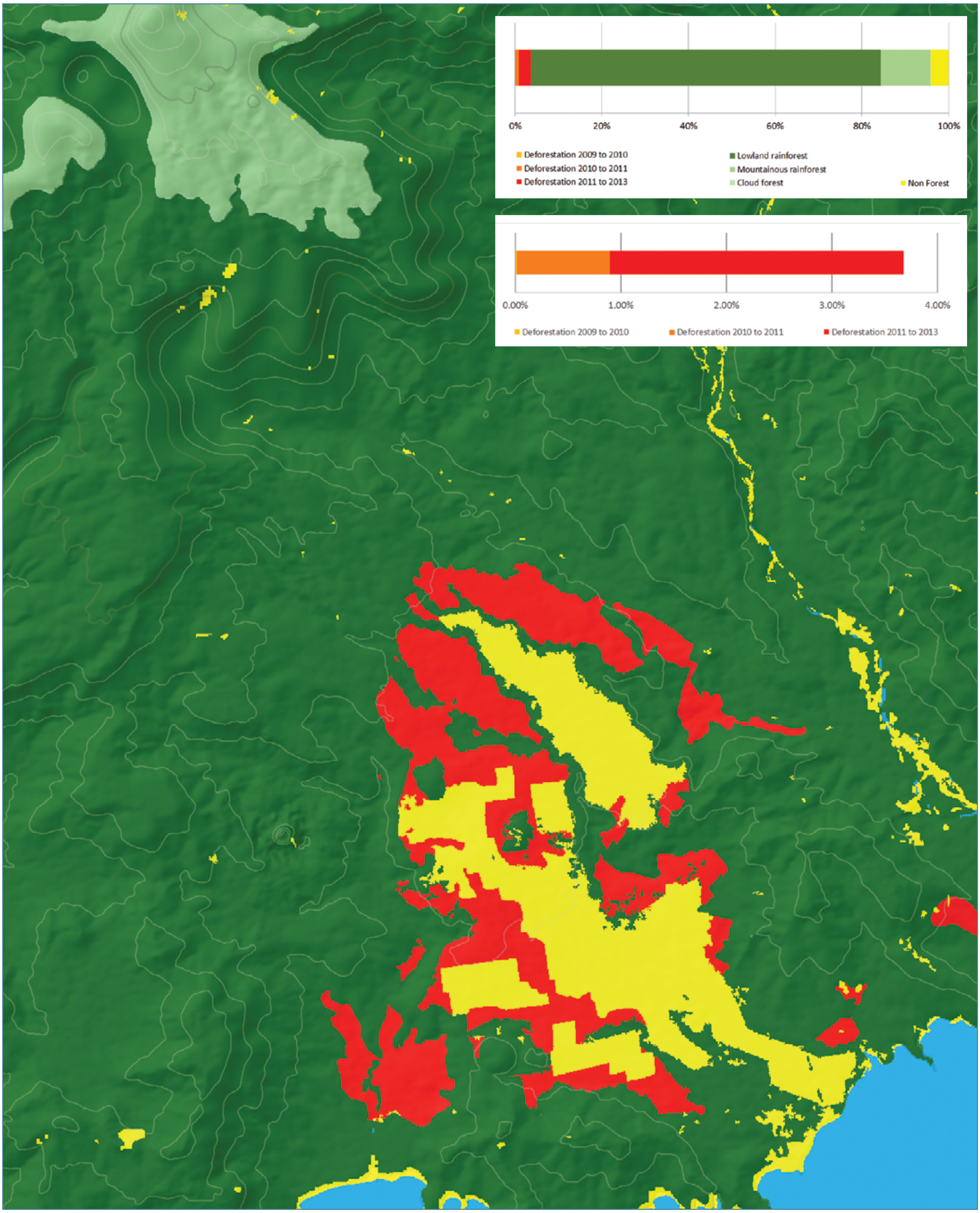
(center) and Guadalupe/Conde (northeast). The most important hotspot is the deforestation area around Monte Café, which is inside the ONP buffer zone.

Figure 3 shows a more detailed example of the forest clear cuts and deforestation mapping in a large oil palm plantation area in the South of Sao Tome. A total area of 1260 ha (12.6 km²) was lost between 2009 and 2013 due to deforestation, out of which 58 ha (0.58 km²) are inside the ONP core zone, 744 ha (7.44 km²) in the buffer zone and 458 ha (4.58 km²) outside the ONP.

The highest deforestation rate, in the complete project area, of 1.28 % (874 ha) was monitored in the latest period 2011-2013.

The ONP buffer zone shows with 3.68 % the highest overall deforestation rate over the complete monitoring period (2009-2013).

Figure 3: Forest clear cuts and deforestation yearly mapping example



In addition to the forest change maps, a highly precise Digital Terrain Model derived from stereographic TerraSAR-X imagery (3 m) was generated to provide terrain elevations of vegetation and man-made objects with a horizontal and vertical accuracy of approximately 5 m. In terms of resolution and accuracy, such a product is significantly superior to free elevation data, such as SRTM or ASTER GDEM, and can be used for more refined analysis on terrain characteristics and hazard risk analyses (e.g. landslides). This elevation information was also used to define elevation dependent forest types. Figure 4 shows an extract of the TerraSAR-X based elevation model for an area in the South-West of Sao Tome

> “The São Tomé and Príncipe project offers a good example for the practical uses of earth observation technology by showing where deforestation has taken place, indicating likely causes of deforestation and providing a baseline for project evaluation at a later stage. Especially when one considers the decreasing costs of future exercises due to the free data and the possibility of additional applications to the maps, the potential of earth observations is substantial.”

Source: http://ifad-un.blogspot.it/2014_01_01_archive.html

Figure 4: High Resolution Digital Terrain Model (with shaded relief).

TRAINING

A field campaign was carried out in the project area between 10-16 May 2013 by two GeoVille experts. It comprised the survey of ground-truth information within the buffer and small part of the Obo National Park core zone. During the same period, within the context of the World Bank project "High Resolution Coastal Change Maps for São Tomé and Príncipe", a four day training course on "Satellite-based applications for coastal and land monitoring in São Tomé and Príncipe" was held by a GeoVille expert for local stakeholders in São Tomé, including the staff of PAPAFPA.

Field campaign carried out May 10-16 2013.

CONCLUSION AND OUTLOOK

The status of the forest in São Tomé, especially illegal logging activities within the Obo National Park, highlights a real need for a detailed and quality assured assessment of the forest. The previous assessments carried out provided statistics of the forest resources for selective parts of the island, but were unsuitable for a comprehensive assessment of the complete forest within the Obo National Park and buffer zone. The EO services delivered in the Forest Monitoring São Tomé and Príncipe project provided more extensive data for the whole of São Tomé.

The products delivered provided previously non-existent information. From the IFAD perspective it is important to know that there are well established methods to assess the forest and vegetation cover over large areas in a rapid, cost efficient and quality assured way. They will be used by IFAD staff and by local users (especially GEF/PAPAFPA).

Users showed much interest in the products provided, particularly in the forest clear cuts and deforestation products. The products were evaluated as less detailed compared to in situ information but the advantages of comparably little time involvement, comprehensiveness and reduction of expenditure, were emphasised.

IFAD stated that the mapped hotspots of deforestation are due to concessions. The monitoring of deforestation helps IFAD to document the amount of lost forest areas in general as well as in specific areas which are lost to mono-cropping within the concession zones. These mono-cropping activities are contrary to the traditional cropping methods in São Tomé.

The main strength of the São Tomé forest monitoring services lies in the way they distinctly display areas of forest activities, especially in the Obo National Park core and buffer zone. Despite the logging activities that have been taking place in the last four years, the forest resource seems be quite well maintained. This fact is difficult to assess comprehensively in São Tomé without the use of EO products, due to limited infrastructure making field work prohibitively difficult to conduct. These kinds of services are important both for forest resource assessment, biodiversity conservation purposes as well as to establish benchmarks for REDD+ discussions.

FOREST MAPPING IN SÃO TOMÉ	
Service provider	GeoVille
Related IFAD project	Participatory Smallholder Agriculture and Artisanal Fisheries Development Programme (PAPAFPA)
Potential for IFAD Sectors	 Monitoring of land degradation and deforestation

→ HISTORIC CROP TYPE MONITORING IN VIETNAM

© IFAD / Louis Dematteis

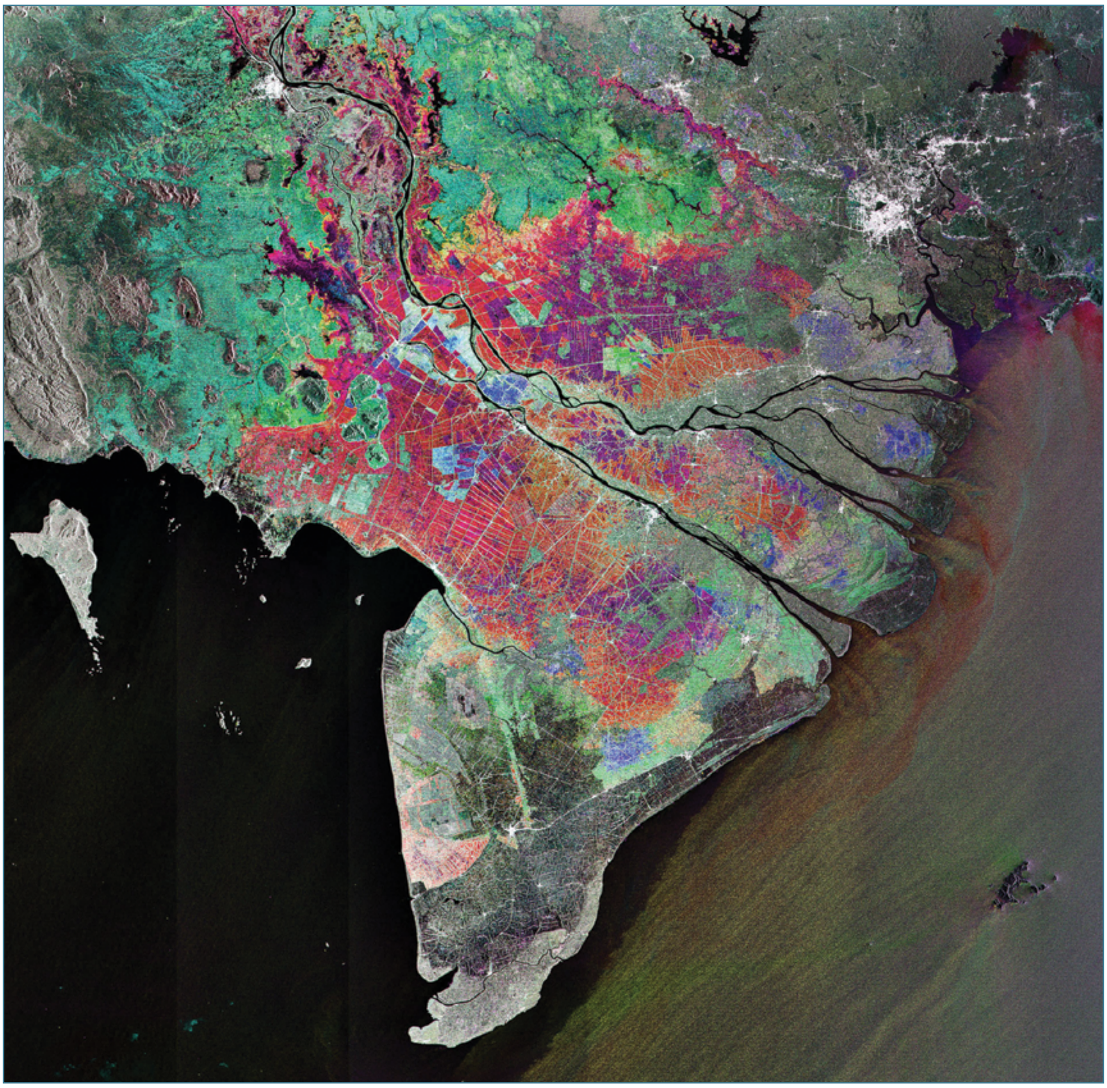
Rice is one of the most important nutrition components in the World and a supply of stable food in many countries, especially in Southeast Asia. Vietnam is the leading producer of rice in the World, and Mekong delta region being the most important rice production area.

Up-to-date information on areas under rice cultivation and changes in the cultivated area over years is essential for the national political decision-makers and for the international trade organisations.

EO CONTRIBUTION

In order to detect long-term changes in land-use, an EO dataset covering a time period of around 30 years was acquired. Due to the frequent cloudiness of the Mekong delta region, the main challenge in this project was to obtain cloud-free archived optical EO data. Therefore, radar satellite data were also used for creating land-use maps. The final EO data set covered the time period from 1979 to 2012 and consisted of a total of 37 SAR (ENVISAT ASAR) and 12 optical images (LANDSAT, SPOT, Kompsat). The land-use maps for the respective years were produced: 1979 (Landsat), 1987 (SPOT), 2002 (Landsat), 2005 (SPOT), 2005 (Envisat ASAR), 2009 (Envisat ASAR), 2011 (Envisat ASAR).

Automatic image classification procedures were used to map land-use and land-use changes in the Tra Vinh and Ben Tre provinces. The following land-use classes were used in the final products: Water, Irrigated rice crop (two crops per year), Aquaculture, Rainfed rice (two crops per year), Rainy season rice & shrimp culture, Settled areas, Coconut, sugar cane and orchard, Irrigated rice crop (three crops per year), and Urban areas. The map products of the project were also validated based on the ground truth points collected during a field survey campaign in October 2013.



Spaceborne radar and optical instruments are used to provide complementary information. Radar works in all weather, able to peer through cloud, rain and darkness, as demonstrated by this Envisat Advanced Synthetic Aperture Radar (ASAR) image of Vietnam's Mekong Delta – which is typically covered by cloud.

Credits: ESA

Although, some of the central descriptive data on cultivated areas are recorded by the national authorities, there is still need for more accurate and timely information with longer temporal perspective, which can be obtained by using Earth observation (EO) satellites.

This project was set up to demonstrate Earth observation (EO) information services for the International Fund for Agricultural Development (IFAD) by producing land-use maps, with special emphasis on rice cultivated areas, from satellite images in a target area in Vietnam, in the Mekong delta region covering the provinces of Ben Tre and Tra Vinh.

The main objective of this project was to detect and measure land-use changes in the target area: however, the results can be further exploited to evaluate the effect of salinity intrusion to land use with the aim of defining the rice growing areas that need to change to other land uses due to increasing salinity.

RESULTS

The final products consisted of pre-processed EO images, digital land-use maps with their metadata, and numerical data on changes in land-use. The products covered the target provinces of Tra Vinh and Ben Tre. Numerical data on land-use per district (17 districts in total) was also provided. The numerical results can be used to interpret land-use changes in the area, especially changes in rice, aquaculture and settled areas. Because of the non-optimal acquisition dates of the optical EO data, acquisition dates should be considered when interpreting the results.

SAR EO data in particular enabled creation of reliable, wide-area, and up-to-date information on the historical land-use. Land-use maps revealed that the rice acreage has decreased and the aquaculture and coconut/orchard acreages have increased in the target area during the last 30 years. Between 2005 and 2011, the biggest changes were in the inland areas, with most of the changes in the coastal area apparently taking place before 2005. This result was supported with the historical optical EO data (1979-2005), and was verified by the farmers during the field survey campaign. The interviews with the local farmers during the field survey campaign provided valuable contribution to analysing the reliability and the accuracy of the land use classification data.

The results of the project were limited by the amount of EO data available in the satellite image archives. Only a few cloud free images were available from a sample of optical EO data taken over the last 30 years. Moreover, there were some gaps in the areal coverage due to the cloudiness. Based on the optical images it was not possible to distinguish multi-year rice from single season rice. Although SAR data was acquired with the wide-swath mode of ASAR (with some 150 meters spatial resolution), SAR appeared to be more promising data source for creating land-use maps for this project. This is because of the cloud penetration capability of SAR, which enables the analysis of multitemporal data throughout the year. In the future, in order to carry out land-use mapping and detect changes in land-use, it is vital that EO data is collected systematically from the target area.

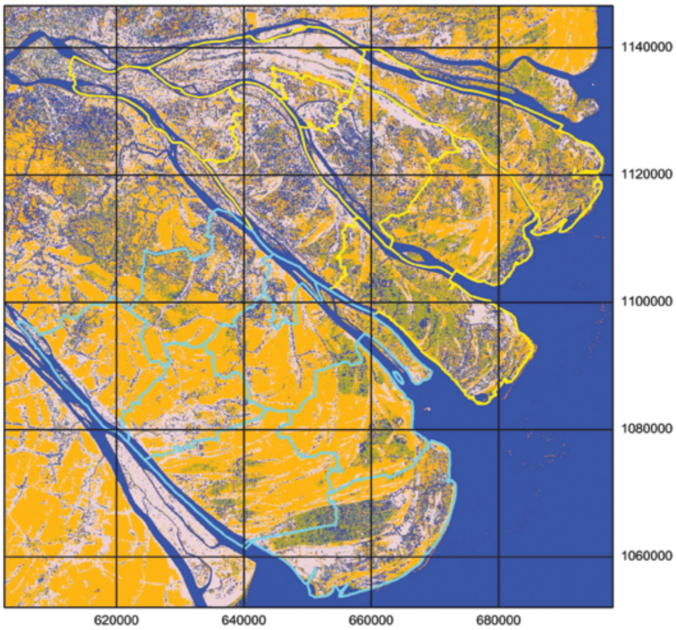


Figure 1: Land-use classification based on Landsat 1979

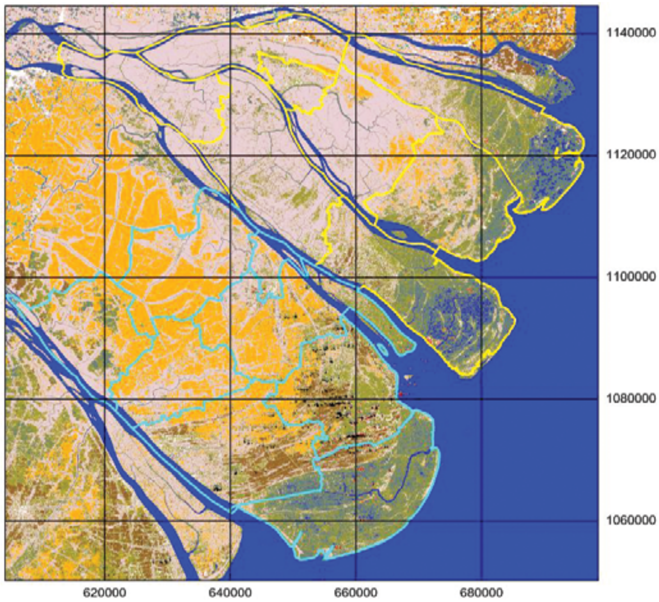


Figure 2: Land-use classification based on SPOT 2005 data

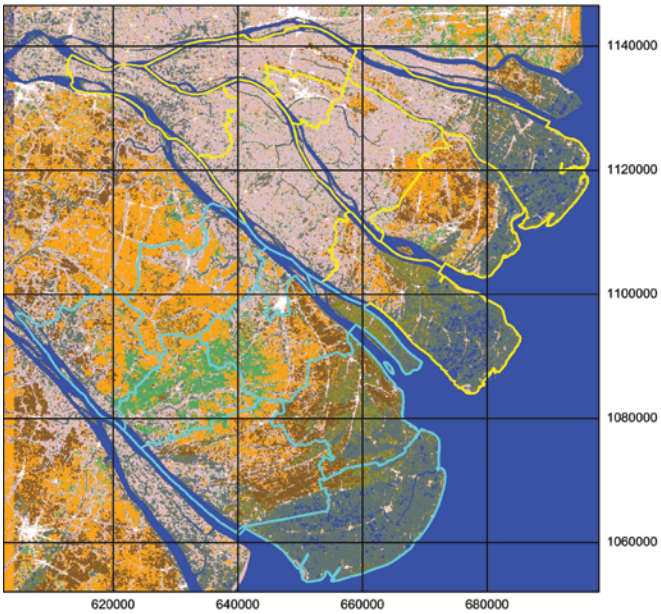


Figure 3: Land-use classification based on Envisat/ASAR WideSwath 2011 data

The spatial resolution of the final products in this project was limited to the resolution of the satellite data available. Modern high resolution SAR satellites, such as TerraSAR-X, COSMO-SkyMed, Radarsat-2, and Sentinel-1, would give more detailed results on the land-use. However, the amount of data-takes also increases due to the smaller image coverage, which also limits the total area under investigation. In the future, from the rice mapping point of view, the use of Sentinel-1 satellites appears promising due to the continuous wide-area monitoring capacity and good temporal coverage over areas such as the Mekong delta region. Up-to-date land-use maps from Vietnam are constantly needed to detect long-term trends in land-use and to use as an aid in decision making when policies concerning farming actions are planned, and this information can be produced from EO data.

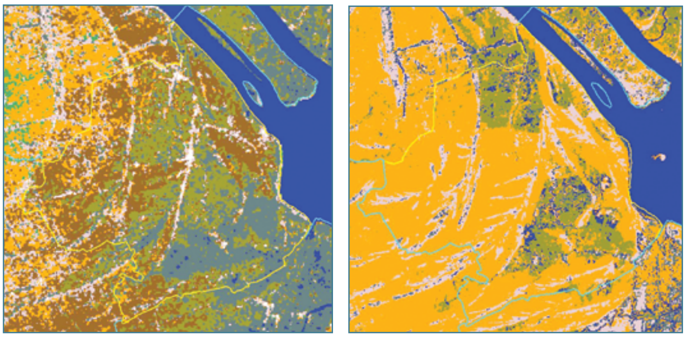


Figure 4: Zoom of land use change from 1979 (left) to 2011 (right)

Legend for images 1, 2,3 and 4

- Unclassified
- Water
- 2 x Irrigated ice crop
- Aquaculture
- 2 x Rainfed rice crop
- Rainy season rice - shrimp culture
- Settled areas coconut, sugar cane and orchard
- 3 x Irrigated rice crop
- Urban

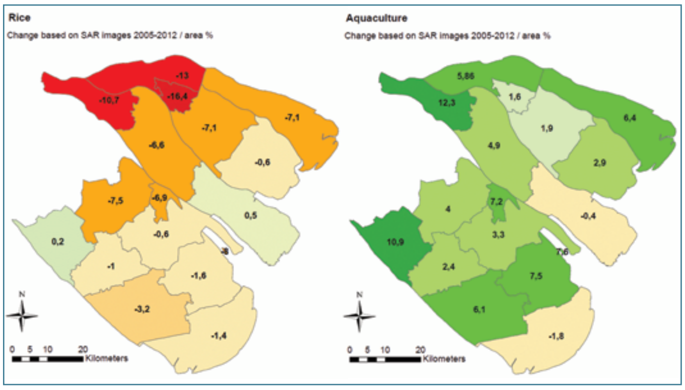


Figure 5: The relative changes in Rice and Aquaculture acreages in the target area

TRAINING

Training was not envisaged within the scope of this project. However, the validation of the final products was carried out using reference data. According to the validation results, the overall classification accuracy of approximately 80% was achieved. Therefore, it is possible to distinguish rice crops from other land-use classes such as aquaculture and coconuts/orchards plants with reasonable accuracy.

Interview with local people during the field survey campaign.

Credits: Olli Nevalainen

CONCLUSION AND OUTLOOK

The strength of the growing satellite archive was demonstrated for the Mekong delta in Vietnam, documenting land use changes from 1979 – 2013. End-user feedback on the land-use maps and historical changes in land-use was very positive. Land-use maps indicated a clear decreasing trend in rice-cultivated area in the target provinces. This trend is in line with the common knowledge. Due to the salinity intrusion in the target area, farmers have gradually changed from rice crops to cultivation of other crops, which are more resistant to salinity than rice.

From the end-user point of view, the most important weakness of the EO service was the unreliability of the land-use maps before 2005 due to the missing validation data. A field survey campaign was carried out in 2013 for the validation task and reliable ground truth was collected for the current land-use situation. During the field survey campaign, historical information was also collected for the validation points; however, this information is not perfectly suitable for the time before 2005. Another minor shortcoming was the relatively low spatial resolution of the EO products, which originates from the resolution of the Envisat Wide-Swath data.

Overall, the value of EO data was seen as very high to assess climate and land use change. Satellites are the only possible approach to monitor wide areas such as the Mekong delta region and produce land-use maps frequently enough, e.g., once per year. The coverage the future Sentinels-1 and 2 will lead to a tremendous increase in the archive database of images allowing even better historical change analysis and impact assessments.

Based on the experiences from this project and feed-back of the end-users, the following recommendations can be outlined:

- SAR satellite data appears to be the only possible way to identify multi-year rice crops due to cloudiness in the target area. Optical satellite images can be obtained in the dry-season, but they are not very optimal for rice field identification
- Better spatial resolution than Envisat wide-swath ASAR is needed. Land-use maps created from ASAR WS mode images have resolution of some 150 meters, which is not enough to identify fine details in land-use. Sentinel-1 SAR will be a major step forward in the spatial resolution (5 m x 20 m).
- It is important to have ground truth data for the validation of EO products. Without proper validation the EO service has limited reliability and usability in the end-users processes.

HISTORIC CROP TYPE MONITORING IN VIETNAM	
Service provider	Finnish Geodetic Institute
Related IFAD project	Project for Adaptation to Climate Change in the Mekong Delta in Ben Tre and Tra Vinh Provinces
Potential for IFAD Sectors	Climate change adaptation and climate risk management

LESSONS LEARNT

The activities carried out in collaboration with IFAD demonstrated how high quality reliable Earth observation information and technology can support various IFAD activities.

Despite the positive results from these and similar activities, as well as increasingly sophisticated technology and EO observation sensors, mainstreaming data and knowledge products as a standard tool for International Finance Institutions still remains a challenge. The trials presented in this report and conducted for IFAD provided valuable input for developing the sustainable uptake of the individual EO-based services.

A summary of the main conclusions drawn from the activities is given below:

RAISING USER AWARENESS

Allocating time at the start of the project to outline types EO information available is key to ensuring that users' requirements and operational needs are correctly identified and met. ESA recommends having a dedicated IFAD contact who understands the EO service needed, and can function as a buffer between the country manager and the service provider to help identify requirements.

CAPACITY BULIDING

Developing this understanding of EO and GIS within both IFAD and the local users in the developing countries is critical for working with technology in a sustainable manner and to ensure growth in the operating IFAD countries. Without this - particularly in the case of complicated satellite data processing - local users risk producing unreliable outcomes, resulting in discontinued use of an otherwise useful technology.

MAXIMISED USE OF EO DATA

The most effective use of data can be achieved by exploiting the information delivered for a specific project in a wider context. For example, reusing statistics extracted from maps for future reporting etc. Improved understanding is needed on how information can be extracted used and analysed repeatedly throughout GIS systems.

GROUND TRUTH INFORMATION

Involving the local 'ground truthing' capacity for project validation is vital for the assessment and validation of the EO services and will lead to better results.

ACCESS TO IMPROVED ARCHIVES

Long term data archives will be significantly increased with the launch of the Sentinel satellites, providing more complete historic data over particular regions – mitigating analysis problems due to lack of data acquisitions over particular areas.

IFAD ESTABLISHING WORKING PRACTICES WITH EO AND GIS

ESA has worked with IFAD for more than 4 years, organising regular visits, workshops and completion of 8 trials. EO information can benefit many organisational levels in IFAD. On a project level, various EO services and products can benefit the individual operating countries including: Environmental impact assessments, Results-based country strategic opportunities programme (COSOP) analysis and project monitoring and evaluation. Cross cutting all this is Monitoring and Evaluation (M&E) normally done by the Independent Office of Evaluation (IOE). This office evaluates reports on project, country programme, thematic and corporate level and compiles these in the Annual Report on Result and Impact (ARRI).

The ARRI takes into account a number of reports, assessing the state of work, such as the project completion report (PCR), and validates this against the Result and Impact Management System (RIMS). The RIMS defines global indicators which provide information about the project progress and allows evaluation of the success of the project. Some of these indicators can also be mapped by EO.

The arguments for a sustainable uptake of EO and GIS as well as the need for increased use of EO & GIS at IFAD have been acknowledged internally at IFAD and is now being taken forward by IFAD staff members. In the Fall of 2013, as a result of ESA projects and other similar geospatial activities, a dedicated group of IFAD staff was set up to establish an examination of IFAD's use of EO and GIS[4]. The goal of the group is to: "Enhance the effectiveness and impact of IFAD supported activities through more systematic use of EO and GIS technologies in the Fund's operations."

These goals shall be met by working with the following objectives :

- Familiarise IFAD staff with information, resources and developments in EO and GIS applications;
- Help identify how EO techniques and GIS tools can be incorporated into IFAD-supported projects and other activities to add value
- Facilitate access to international centres of excellence and networks of experts to enable IFAD staff to practically engage with EO/GIS in support of their activities
- Raise awareness at all levels of the Fund as to the potential and importance of expanding IFAD's activities involving EO/GIS.

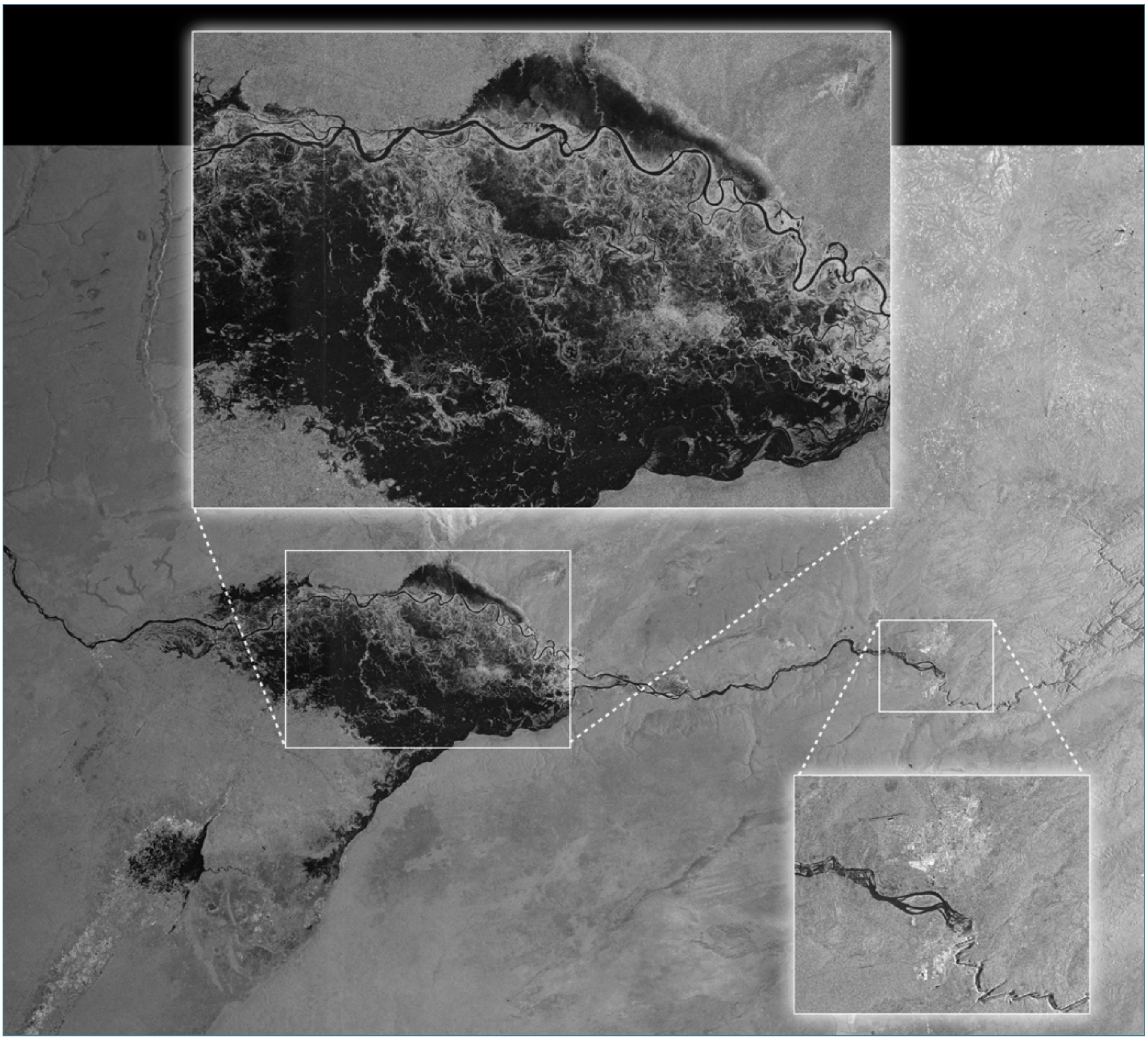


Image shows the extent of flooding in the Caprivi plain from the Zambezi River in Namibia as seen by Sentinel-1 . The image was downloaded two hours after acquisition and the resulting products were available in less than an hour. Such images can be taken in adverse weather conditions and during the dark, demonstrating the value of Sentinel-1's radar vision.

[4] The following has been printed with the permission of the relevant IFAD staff.

THE WAY FORWARD

Although findings are preliminary, this group plans to partake in a number of activities to enable full evaluation across the organisation:

INFORMATION SHARING

Share information, knowledge and build capacity in IFAD

- Promote exchanges on key issues, topics, and developments in EO/GIS, including lessons learned from relevant experiences within and outside IFAD;
- Provide access to existing resources IFAD staff can utilise, e.g. ESA's portfolio of verified service providers or the ICRAF Geoscience Lab;
- Create new linkages for cooperation with relevant expertise e.g. WFP VAM Unit or FAO GIS units.

USER EXAMINATIONS

- Contribute to defining IFAD's user needs
- Identify the key cross-cutting issues, challenges, and needs in IFAD's use of EO/GIS and recommend targeted measures to improve the organization's ability to work with and fully benefit from these applications (e.g. information requirements, technology, staffing, and partnership needs).

PROMOTE WIDER ADOPTION OF EO AND GIS IN IFAD

- Understand how to take better advantage of upcoming opportunities, e.g. data provided by Sentinel II satellites at no cost
- Identify key resources and funding sources to support EO-GIS activities, e.g. different ESA pilot funding; Netherlands Space Office G4AW initiative
- Strengthen partnerships with ESA, WMO, WFP, CGIAR and other industry players

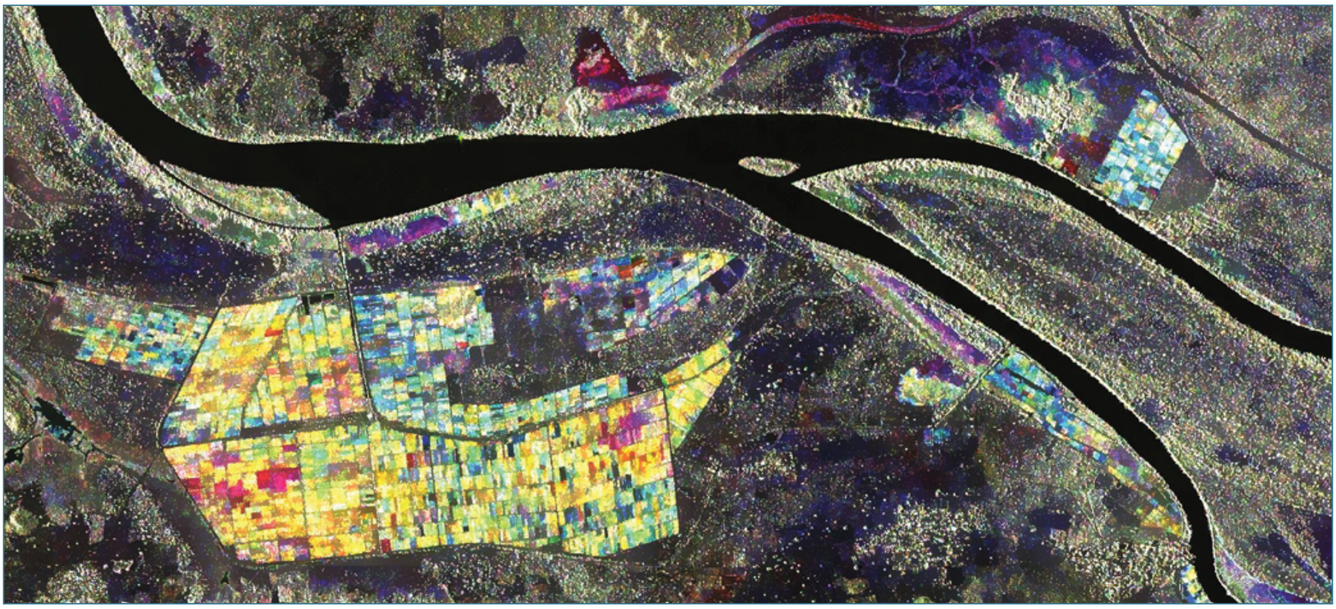
WITH THE NEAR-TERM OUTPUTS TO ESTABLISH

- Strategy and work plan on how to better integrate the use of EO/GIS in IFAD
- At least 3 relevant learning/knowledge sharing events organised (e.g. progress/results from the five pilot countries supported by ESA)
- Cooperation established with at least 2 institutions, e.g. WFP VAM Unit
- Relevant EO-GIS information resources and developments shared through CoP
- Sharepoint site; dedicated email address; and at a wider scale where appropriate (e.g.IFAD's daily news clippings email; IFAD website)

On IFAD's request, ESA aims to help this process to ensure the best possible integration of new satellite /GIS technology and analysis in IFAD's organisation and projects.

Gambia Rice paddies and agriculture as seen by radar satellites at 3 m resolution.

Credits: Sarmap and Cosmo-SkyMed



FUTURE ESA MISSIONS: THE SENTINELS

With the start of the European flagship space program Copernicus, the European Union and ESA provide the framework for the development of the operational Earth observation system of a new generation. ESA is developing six families of new Sentinel missions specifically for the Copernicus programme, the first of which was launched in 2014.

- Sentinel-1 to be used for land and ocean services
- Sentinel-2 which will deliver high-resolution optical images for land services
- Sentinel-3 for services relevant to the ocean and land
- Sentinel-4 and Sentinel-5 for atmospheric composition monitoring from geostationary and polar orbits
- Sentinel-6 to measure global sea-surface height, primarily for operational oceanography and for climate studies

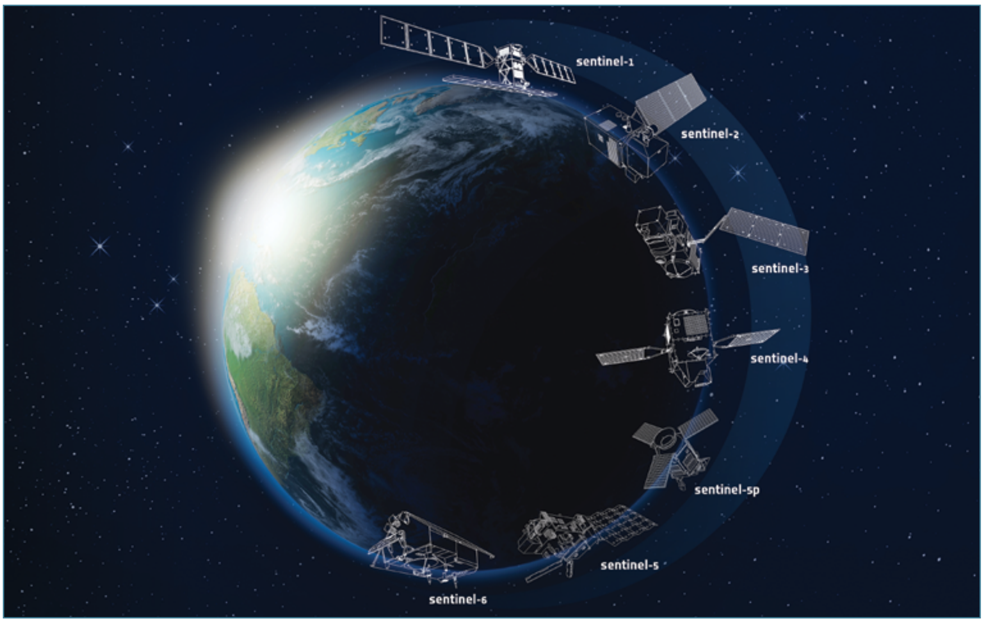
The Sentinel missions will provide worldwide carpet coverage resulting in an unprecedented increase in the amount of Earth observation data available to the users, while guaranteeing a long-term continuity of observations for future decades (25+ years).

Along with the Sentinels, there are around 30 existing or planned missions contributing to the Copernicus programme. These include missions from ESA, their Member States, Eumetsat (European Organization for the Exploitation of Meteorological Satellites) and other European and international TPM. Sentinel Data Policy Principles includes full and open access to Sentinel data to all users.

Copernicus services will provide essential information for six main domains: ocean, land and atmosphere monitoring, emergency response, security and climate change:

- Services relevant to the marine environment include monitoring for marine safety and transport, oil-spill detection, water quality, weather forecasting and the polar environment.
- Services relevant to the land environment include monitoring for water management, agriculture and food security, land-use change, forest monitoring, soil quality, urban planning and natural protection services.
- Services relevant to the atmospheric include monitoring for air quality and ultraviolet radiation forecasts, greenhouse gases and climate forcing.
- Services for emergency management response will help mitigating the effects of natural and manmade disasters such as floods, forest fires and earthquakes and contribute to humanitarian aid exercises.
- Services for security will support peacekeeping efforts, maritime surveillance and border control.
- Services for monitoring climate change cross-cut all of the above domains.

As part of the Copernicus Space Component programme, ESA manages the coordinated access to the data procured from the various Contributing Missions and the Sentinels, in response to the Copernicus users' requirements.



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NIGER Land use and erosion risk

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Special thanks to the service providers for providing the main content of the report.

Most of the Country program Managers from IFAD's side, managed these projects services on top of their full time busy work schedule. ESA is therefore very grateful to Vincenzo Galastro, Moses Abukari, Geoffrey Livingstone, Andrea Serpagli and Roshan Cooke, for taking these extra activities on board to assess the use of EO for IFAD activities.

Finally, a special note of thanks goes to Mr. Benoit Thierry at IFAD, who, as Country Programme Manager of Madagascar in 2008 had the vision and innovation to look into a completely new technology ('EO pictures') and start first discussions that led to the further IFAD - ESA collaboration of this report.

Cover Page

Front page Cover satellite: Senagal and Casamance seen by Landsat 8

Credits: USGS/ESA

Front page Cover real life: ©IFAD/Olivier Asselin

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