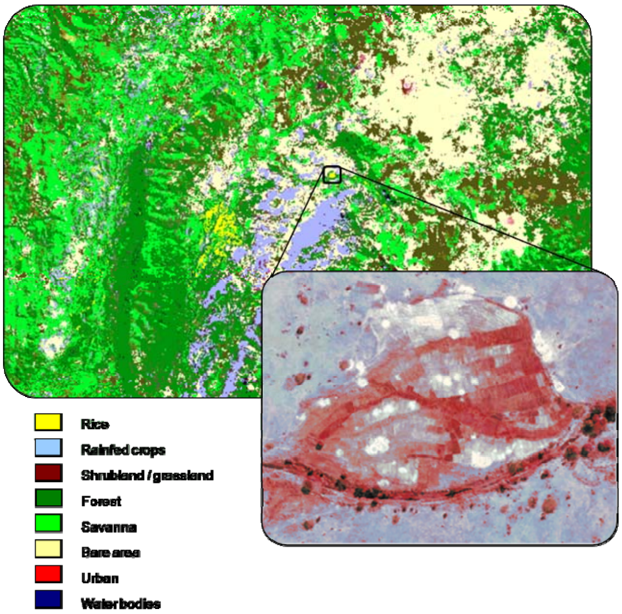
EARTH OBSERVATION FOR INTERNATIONAL FINANCIAL INSTITUTIONS (EOFI)

Contract No. 4000100934/10/I-AM

Service Trial 1: UN-IFAD – Crop acreage

D5 Final Report



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Reference Documents:

RD1	EOFI Statement of Work	EOEP-VAET-EOPG-SW-09-0003
RD2	EOFI ITT	ESRIN/AO/1-6276/10/I-AM
RD3	Project proposal for EOFI Service trial #1	ESRIN AO1-627610I-AM_ EOFI_GeoVille_Proposal I1, 11/03/2010
RD4	Clarifications to technical project proposal	EOFI_ServiceTrial1_Clarifications_GeoVille ; 17/05/2010
RD5	EOFI contract	Contract No. 4000100934/10/I-AM
RD6	Minutes of the Kick-off Meeting in Rome, 09/06/2010	IFAD - ESA Kick-Off Meeting Minutes 9 June 10_final.doc
RD7	EOFI D1 Service Readiness Review	EOFI_Servicetrial1_D1_Service_Readiness_Review_I1.0_20100720.doc
RD8	EOFI D2 Final Products	
RD9	EOFI D3 Operational Documentation	EOFI_Servicetrial1_D3_Operational_Documentation_I1.0_English.doc
RD10	Review Item Discrepancies to D2/D3	RID-D2&3_trial1_GeoVille.doc
RD11	EOFI D4 Service Utility Report	EOFI_Servicetrial1_D4_Service_Utility_Report_D1.0_English.doc

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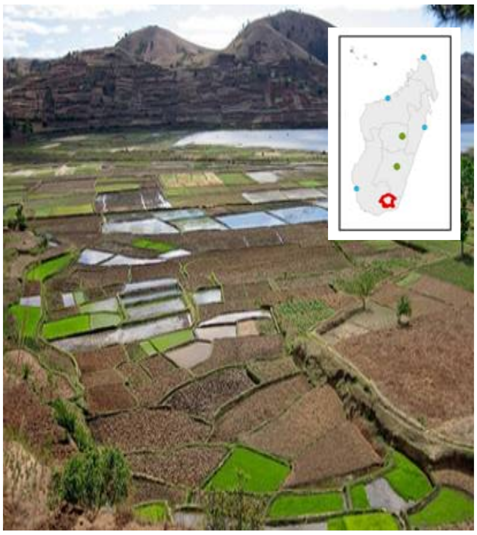
1 Scope of document

The Final Report (FR) documents the main activities and achieved results during Service Trial #1 – Crop Acreage in the frame of the project EOFI (Earth Observation for International Financial Institutions). It contains an executive summary of the project deliverables D2 (Final Products), D3 (Operational Documentation) and D4 (Service Utility Report).

The work presented in this final report is part of ESA's programme entitled **Earth Observation for International Financial Institutions (EOFI)**. The purpose of the activity is to demonstrate and validate with initially small-scale trials the utility of currently available Earth observation information services for the objectives and procedures of International Financial Institutions (IFI).



GeoVille has been awarded with an EOFI contract for service trial #1, aiming at the **monitoring of crop acreage in support of UN-IFAD (UN International Fund for Agricultural Development)** funded projects PHBM (Upper Mandraré Basin Development Project) and AROPA (Support to Farmers' Professional Organizations and Agricultural Services Project).

The service is driven by the requirements of UN-IFAD, supported IFAD projects and the Malagasy Ministry of Agriculture, Livestock and Fisheries as a local stakeholder.

EO derived land cover and land cover change maps with a focus on rice and rainfed crops for the PHBM project area (8,300 km²) in the upper Mandraré basin in south-east Madagascar are provided. A time span of 14 years (1996-2010) is observed by mapping of 4 dates (1996, 2000, 2007, and 2010).

Project activities started in June 2010. The first phase was devoted to an in-depth service review to derive consolidated technical specifications and achieve readiness for product generation. Resulting products have been delivered to IFAD in October 2010. This final report concludes the project and the service assessment by UN-IFAD and local stakeholders.

2 Background of the EO service

International financial institutions provide financial support and professional advice for development activities on local to regional scale in developing countries. Their activities are generally organized in dedicated projects financed by long-term loans or grants covering social and economical development aspects in a wide range of fields.

Specifically, UN-IFAD (UN International Fund for Agricultural Development) is dedicated to eradicating poverty in the rural areas of developing countries and its activities focus on agricultural and rural development. Further the mandate of UN-IFAD is aiming to mobilize additional resources to be made available on concessional terms for agricultural development in developing Member States.

Since 1979, IFAD has funded 13 rural development projects in Madagascar for a total of US$ 156.9 million. IFAD's Country Strategic Opportunities Programme (COSOP) for 2007-2012 sets its priority towards promoting pro-poor regional development, using participatory approaches, to ensure that the more vulnerable producers and their families can benefit from rural economic growth and achieve better livelihoods.[1]

IFAD's strategy for 2007-2012 has the following three main thrusts:

- Establishment of management mechanisms for risks associated with production and the land tenure system by improving the access of the poor to resources and services
- Improvement of poor farmers' income through diversification of agricultural activities, development of rural microenterprises and improved market access
- Professionalization of poor producers and their organization so as to include them in economic development and policy dialogue

At the end of the 1970s, the main objective of IFAD's programmes and projects was to increase agricultural production, especially that of irrigated rice and livestock, and to ensure rural inhabitants' food self-sufficiency. Since the 1990s projects have the aim of diversifying agricultural production, increasing rice production, developing new zones in order to reduce population pressure on the central highlands, and helping to create farmers' organizations.

The aim of the UN-IFAD funded projects PHBM/AROPA in south-east Madagascar is the enhancement of integrated multi-sectoral rural development in the upper basin of the Mandrare river (PHBM)[2] and the support to farmers' professional organizations and agricultural services (AROPA).[3]

[1] http://operations.ifad.org/web/ifad/operations/country/home/tags/madagascar
[2] http://www.phbm.mg/
[3] http://www.capfida.mg/se/site_spip/spip.php?rubrique64

Upper Mandraré Basin Development Project (PHBM)

The goal of PHBM under the Ministry of Agriculture, Livestock and Fisheries of the Government of Madagascar was to stop the process of impoverishment which had reached alarming proportions. The project contributed to

- diversification and sustainable growth of household incomes
- improving food security and
- restoration and sustainable management of natural resources.

Through the investments, the area in the regions of Androy and Anosy has grown from a difficult food situation, of isolation and institutional vacuum to a surplus in food products, to open markets and has strong rural organizations.

The first phase of the Upper Mandraré Basin Development Project (1995-2001) was designed to strengthen farmers' organizations so that they could participate in regional development and establish rice granaries in the south, following the recurrent famines of past decades. In total 4,400 households were directly benefiting.

Key facts:
Total cost: US$ 8.4 million
IFAD loan: US$ 5.3 million

The recently completed Upper Mandraré Basin Development Project – Phase II (2001-2008) managed to boost food production through extended irrigation schemes from 1,000 ha to 5,000 ha, consequently attaining rice production levels of 25,000 tons per year (doubling average increases in yields from 1.7 to 4.3 tons per ha). Some 23,723 rural households hence strengthened their food security over an original target of 17,400.

Key facts:
Total cost: US$ 23.1 million
IFAD loan: US$ 12.6 million
Cofinancing by World Bank: IDA (US$ 3.6 million)

Support to Farmers' Professional Organizations and Agricultural Services Project (AROPA)

The goal of AROPA (2009 – 2018) is to strengthen existing farmers' organizations, with the aim of improving agricultural production and increasing the incomes of rural households. The target population consists mainly of 75,000 poor rural households belonging to 1,000 farmers' organizations at grass-roots level. The project will boost agricultural production by supporting farmers and their membership in farmers' associations and value-chain organizations.

Key facts:
Total cost: US$ 56.4 million
IFAD loan: US$ 18.7 million / IFAD grant: US$ 515,000
Cofinancing by African Development Bank (US$ 8.2 million), European Union (US$ 10.4 million) and World Bank: IDA (US$ 9.3 million)

In order to better understand the land changes, determine the changes and current state of agricultural production and being able to better contribute to the main objectives of the IFAD projects PHBM and AROPA, UN-IFAD and the Ministry of Agriculture, Livestock and Fisheries require **accurate maps on land cover stocks and change**.

Based on these requirements, ESA and UN-IFAD have jointly defined initial specifications for an Earth Observation based information service dealing with the mapping and monitoring of crop acreage, with a focus on rice and rainfed crops. In this service trial, the use of EO derived land cover information as a tool to support the monitoring and management of selected UN-IFAD projects and to improve the efficiency of the investments made shall be evaluated and the impact and benefits of the service shall be assessed.

As demonstration area the upper Mandrare basin in south-east Madagascar has been selected, which is the area targeted by the UN-IFAD funded Upper Mandraré Basin Development Project (PHBM) and is also part of the AROPA project area.

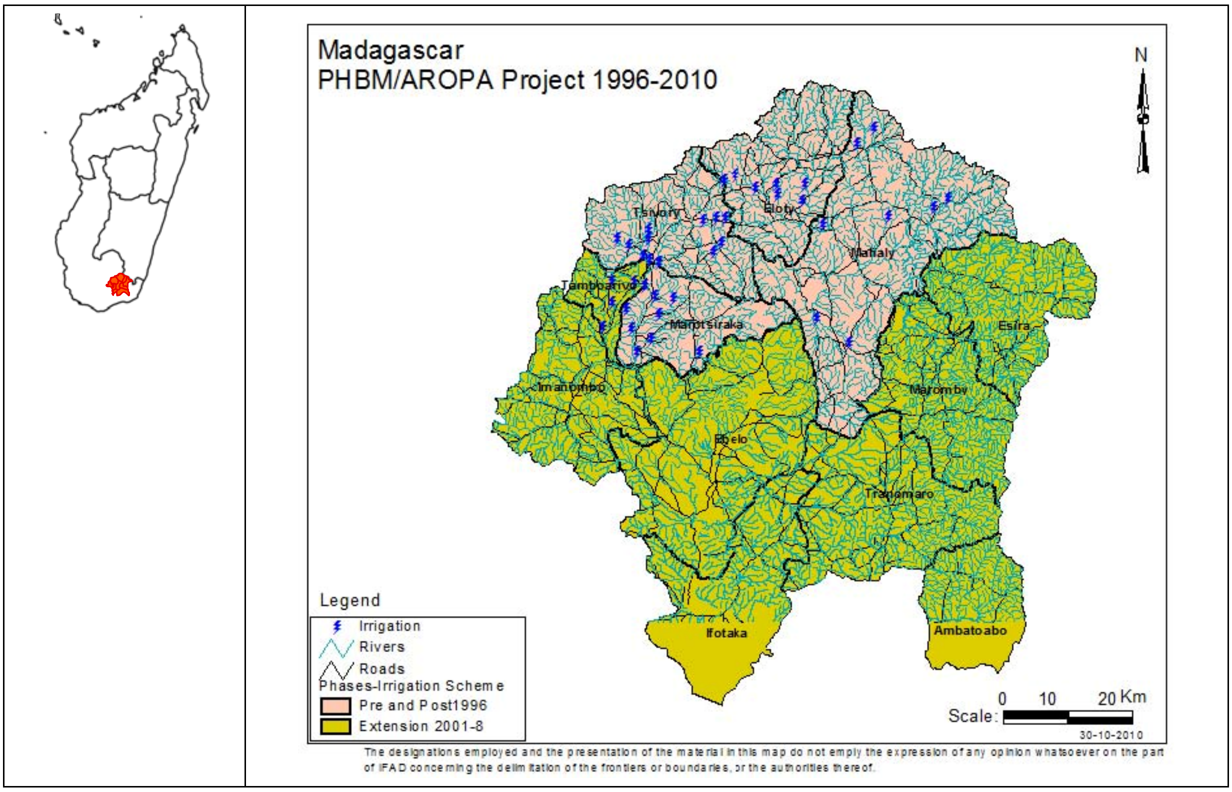


Figure 1. Intervention phases in PHBM/AROPA Irrigation Programme 1996-2008 in the upper Mandrare basin

Task 1 of the project (service set-up) took up these initial requirements and aimed at consolidating the service scope, setting up and verifying the access to EO and in-situ data and defining a validation protocol and success criteria for the service.

3 EO Service: Monitoring of Crop acreage

3.1 Scope of service

The EO service provides status and change maps on crop acreage, including rice and rainfed crops, over the lifetime of the UN-IFAD funded projects PHBM and AROPA in south-east Madagascar.

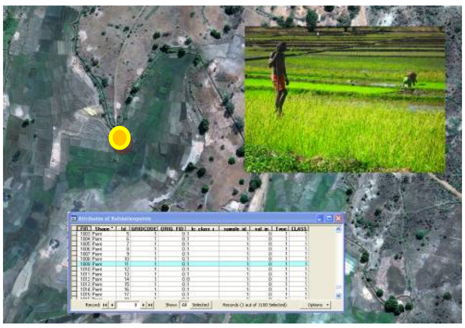
The main challenge of the project is the processing and interpretation of EO radar (ERS, ALOS-PALSAR) and optical satellite data (SPOT, ALOS-AVNIR, LANDSAT, KOMPSAT) of various spatial, spectral and radiometric resolutions and heterogeneous seasonal acquisition windows, in order to produce 4 homogenous land cover datasets in time with equal accuracies.

Task 2 of the project (Production and validation of EO Products) targeted the collection of the EO- and in-situ data, actual production, internal validation and performance assessment, and delivery of the land cover maps and the land cover change assessment.

3.2 Input data

Detection and monitoring of rice fields usually requires multi-temporal / multi-polarisation radar data. Cropland is characterised by a large heterogeneity of land cover, and its appearance is largely different throughout the year (partly flooded / partly dry, vegetated / non-vegetated) and depending on varying vegetation growth stages. It is therefore indispensable to carefully select suitable radar and optical EO data, considering as far as possible planting/growing periods of rice and rainfed crops in the project area.

Investigation of the available archive imagery revealed that satellite data availability is rather poor. The lack of multi-temporal / multi-polarisation SAR imagery and acquisition dates outside the planting/growing period of rice causes an influence on the achievable thematic accuracies. Despite this drawback, satellite data represent the only information tool providing blanket coverage at four dates for the area of interest.



Various additional data sets have been used as reference, involving terrain data, topographic maps, road and river network data, and administrative boundaries. Calibration of the classification algorithm was supported by ground-truthing information, including a set of GPS point samples for selected land cover types and photographs that have been collected by local experts in the field in August 2010.

3.3 Production methodology

Production methodology is based on innovative EO mapping technology employing semi-automated land cover classification and change detection. This is achieved by the application of GeoVille's industry awarded processing chain RegioCover© in a "moving window" change detection approach. Entire production is embedded into an ISO 9001 certified quality management system.

RegioCover© is a highly-automated land cover and land use mapping solution that transforms satellite imagery from optical and radar data into intelligent geoinformation. RegioCover has received the Definiens/ESA/EC GMES Innovation & Research Award 2007 for its innovative and outstanding geo-information processing.

Figure 2. Application components of RegioCover processing chain.

Due to the absence of multi-temporal / multi-polarisation radar data, automated image segmentation and classification is followed by semi-automatic change candidate identification and human verification/falsification.

3.4 Results and validation

The products are digital GIS-ready thematic maps of the main land cover/use types. These include rice, irrigated and rainfed crops that allowing determining the current area under agricultural production and related land cover changes over time between 1996 and 2010. Minimum size of mapped land cover features amounts to 0.8 hectares, i.e. smaller objects are not mapped. Other mapped land cover types comprise forests, grassland, bare areas, urban areas, and water bodies.

Before delivery, an internal validation has been carried out by GeoVille. Validation of the 2010 land cover map has been performed using independent very high resolution satellite data. In the absence of independent data for the other dates (1996, 2000, 2007), validation was conducted using the base EO imagery for production. Resulting overall accuracies of the land cover maps are above 80%. Rice has been detected with 80-85%, rainfed crops with 70-75%, and irrigated crops with 60-70%. Grassland was mapped with approx. 80%, and for other land cover types, such as forest, bare areas, urban areas and water, accuracies are above 85%.

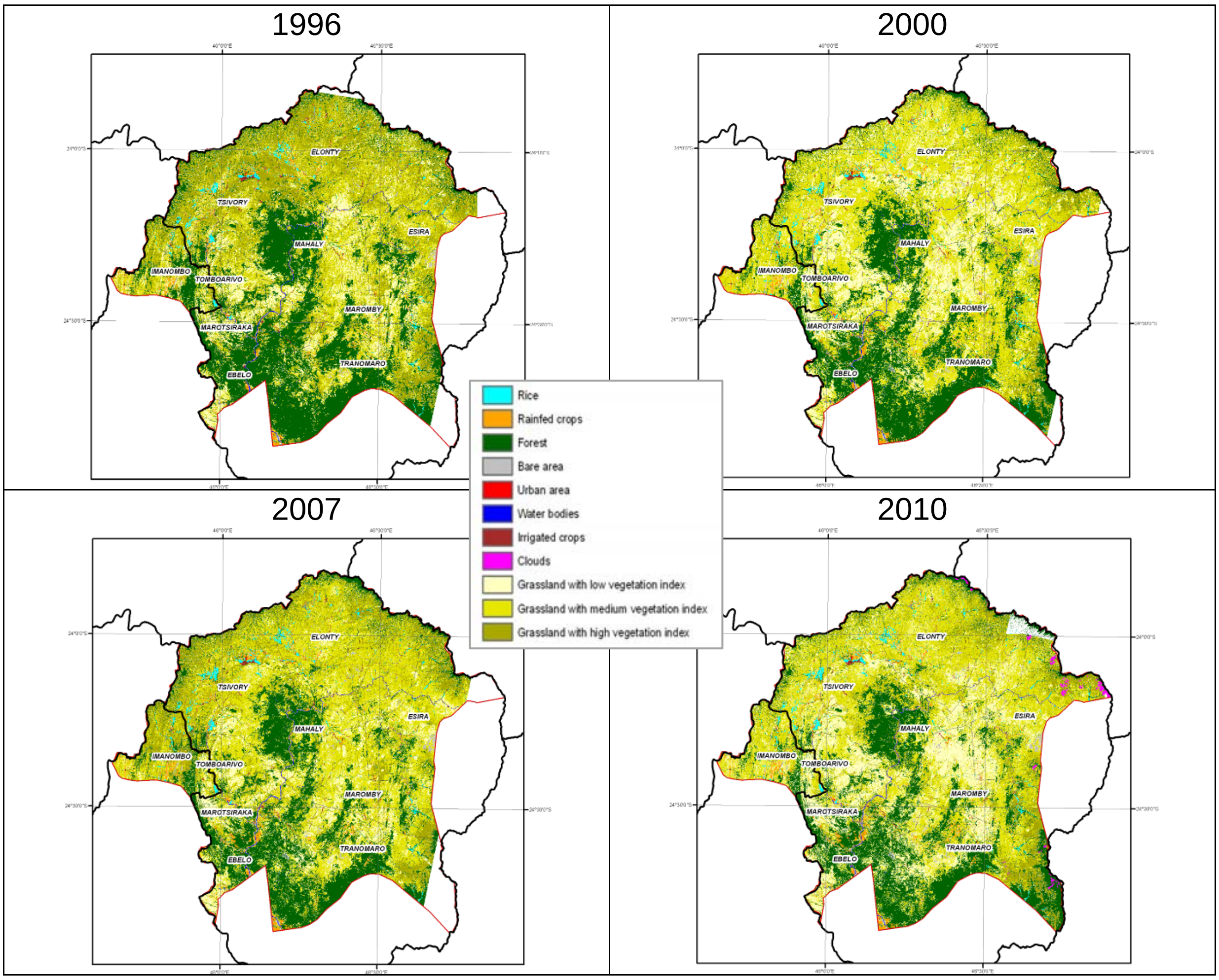


Figure 3. Overview of the land cover maps

The land cover change map – where a sample of 400 change objects has been evaluated – has an accuracy of 87.25%. All in all, the detected land cover changes have a high degree of reliability thanks to the high accuracy of the status land cover maps and the applied process of object-based visual verification by a human interpreter to mitigate the problem of error mitigation.

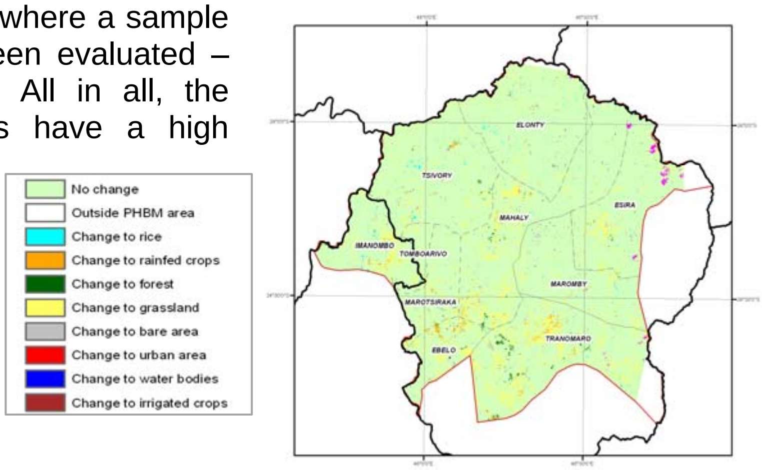


Figure 4. Land cover change map

3.5 Statistical analysis of land cover changes

Statistical analysis of the observed land cover stocks and changes provides consistent and comparable figures and trend information for the entire PHBM project area. The land cover maps allow – with the specified statistical reliability – for a quantification of the actual extent of different agricultural areas and other land cover categories.

Key results from statistical analysis are:

- Grassland and forest are strongly dominating (in 2010 74.1% and 21.5%, respectively), while only 4.4% of the total project area are allotted to other land cover types (rice 1.0% with 82.6 km², rainfed crops 1.6% with 131.7 km², irrigated crops 0.4% with 29.6 km², other non-agricultural land covers 1.4%).

Table 1. Land cover composition 1996-2010

	1996	2000	2007	2010
Rice	6,229.92	7,479.16	8,226.65	8,257.36
Irrigated crops	2,713.15	2,863.94	3,385.20	2,962.46
Rainfed crops	10,213.67	11,896.50	13,425.55	13,164.48
Forest	236,183.61	192,206.97	183,693.83	172,722.73
Grassland	540,636.24	579,639.78	585,700.47	595,338.46
Bare area	3,562.43	5,521.91	5,036.82	5,386.01
Urban area	326.58	396.40	414.10	420.93
Water bodies	3,192.17	3,059.45	3,162.70	3,116.56
No data	6.34	-	18.79	1,695.12

Note: All area values in hectare. Only areas with valid data coverage for all 4 dates are considered. Statistics for individual communes can be provided on request.

- Between 1996 and 2010, cropland experienced a quite substantial increase, predominately at the expense of former grassland and forests. Rice fields grew by 32.5% (20.3 km²), irrigated crops by 9.2% (2.4 km²) and rainfed crops by 28.9% (29.5 km²).

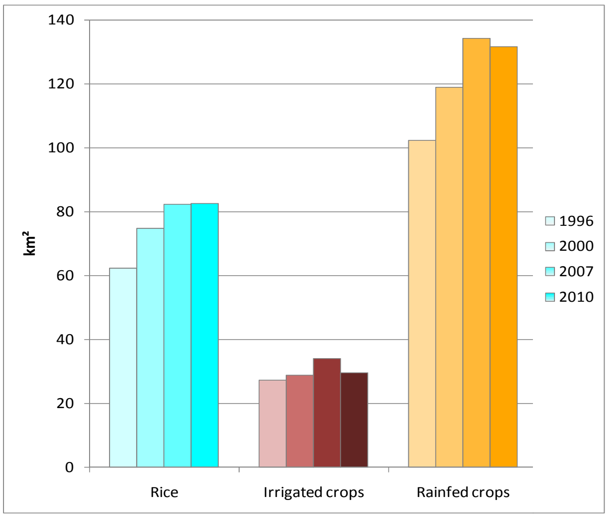


Figure 5. Land cover changes 1996-2010

Rice	+32.5%
Irrigated crops	+9.2%
Rainfed crops	+28.9%
Forest	*-26.9%*
Grassland	*+10.1%*
Bare area	*+51.2%*
Urban area	*+28.9%*
Water bodies	*-2.4%*

- Most important changes of crop acreages between 1996 and 2010 are:
  - From forest to rainfed crops (2,423 ha) and rice (693 ha)
  - From grassland to rice (1,588 ha), rainfed crops (1,252 ha) and irrigated crops (764 ha)
  - From rice to grassland (594 ha)
  - From irrigated crops to grassland (758 ha)

There was a considerable increase of rice fields between 1996 and 2010. The low increase from 2007 to 2010 can be attributed to the following:

- PHBM project came to an end in 2008, hence no investment on irrigation scheme
- Occurrence of drought during the year 2009/2010
- Seasonality of the acquired EO images data. The images for 1996 and 2007 were recorded in spring (end of wet season), i.e. shortly before harvesting at the end of the rice's growth cycle. Those for the years 2000 and 2010 data were acquired in fall (transition of dry to wet season), i.e. at the sowing/growing stage where rice is less visible and areal extents may be underestimated.

The following graph illustrates the absolute change of the land cover classes from 1996 to 2010 and the composition of the growth respectively decline.

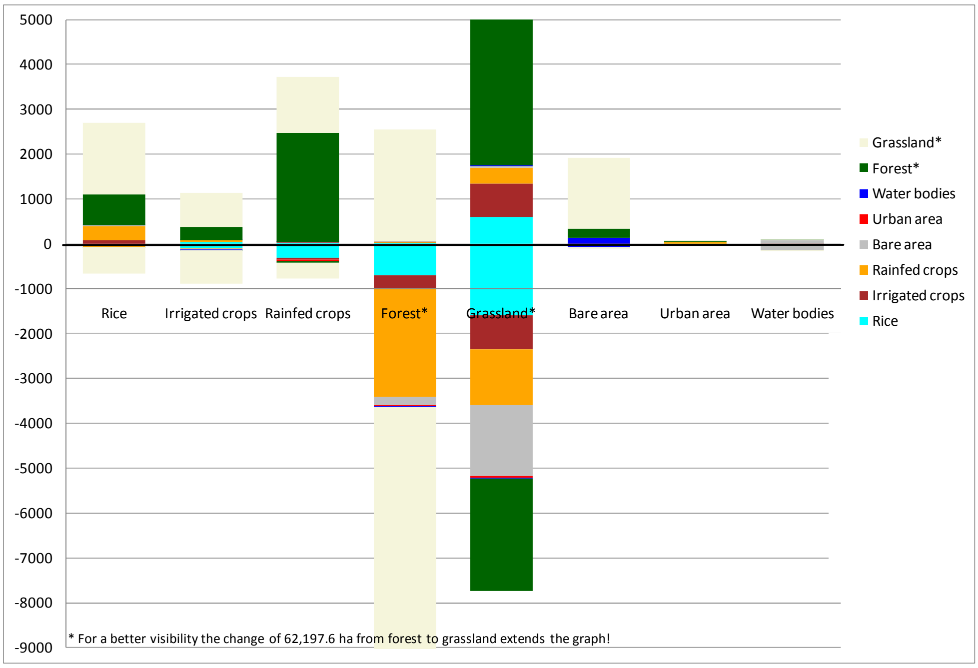


Figure 6. Sources and targets of land cover changes 1996-2010

The mapping products were delivered to UN-IFAD in GIS-ready geo-referenced Tiff-format in local cartographic projection (Laborde Madagascar approché). Metadata are provided in accordance with INSPIRE standards together with the associated product documentation.

4 Impact and benefits of the EO service

Task 3 of the project (Service Assessment) has evaluated the performance, impact and benefits of the delivered service and resulted in requirements and recommendations for future service improvement and evolution.

4.1 Service assessment

After service provision, UN-IFAD has initiated an extensive review process to independently assess the impact, benefits and limitations of the delivered EO products. Feedback has been provided in a dedicated service review report and a service assessment questionnaire. In addition, several external reviewers have been consulted.

IFAD generally states that ***"EO gives us a sound base from which development experts and policy makers can make informed choices."***

IFAD acknowledges that land cover mapping from satellite data always reflects the status of the land surface at the time of data acquisition. The land cover maps produced under service trial #1 do not only show the actual irrigated areas/rice fields used for agricultural production, but also other land use categories of the entire project area. The land cover maps allow - with the specified statistical reliability - for a quantification of the actual extent of different types of agricultural areas (rice, rain fed crops, irrigated crops) and other land cover categories.

The EOFI service is considered an innovative approach, which was not covered so far by other working processes at IFAD and provides information that complements already existing information/working processes. The provided results can be incorporate to refine harvest fields and are therefore a valuable support for the work of IFAD.

According to IFAD the EOFI products are considerably useful and can be used for various areas of applications, such as

- visualizing land cover and its characteristics in maps,
- calculations on crop acreage by type of culture based on the images,
- quantitative and thematic integration with other data, and
- for international (IFAD website) and national reporting (Ministry of Agriculture Madagascar).

The integration of the EOFI products into the technical workflows of IFAD, e.g. monitoring of IFAD projects, is deemed feasible in the long term. For this to happen, there is a need for capacity building on the sustainable utilization of the products as well as reality checks in the field. To be highly useful, this tool should be integrated from the beginning of IFAD's projects, with ground truthing before, during, and after the conclusion of the projects. The model should be extended to harvest and yields to be fully usable.

IFAD has generally acknowledged several limitations pertaining to this service trial that need to be minimized in case of an operational application:

- Limited availability of satellite data: Only a small number of scenes could be acquired in the ideal acquisition window from December to February. Consequently, no multi-temporal / multi-polarisation radar data are available for the requested dates in the project area, especially in the rice sowing and growing period. The mono-temporal / single-polarisation intensity images that have been used do not allow for an unambiguous identification of different land cover types, especially rice, which has a diminishing impact on achievable accuracies.
- Heterogeneity of acquisition dates: The comparison of land cover stocks and change rates has to be always seen in light of the base Earth Observation imagery, which have been recorded at different seasonal dates in the year and at varying vegetation growth stages. This alone affects the degree of accuracy in the interpretation.

IFAD notes that *“**despite the above setbacks, the quality requirements as defined in the Service Readiness Review were however met** as visual interpretation methods coupled with the use of very high resolution Kompsat-2 data were implored during GeoVille’s validation exercise.*” (cf. RD10)

<u>Validation of reported land cover changes</u>

The resulting land cover products and derived change statistics have been intensively discussed with IFAD in order to evaluate the information content and associated limitations. Especially the change rates of rice fields and rainfed/irrigated crops were subject to intensive analysis, as at first glance there is a substantial discrepancy between the agricultural area derived from EO sources and existing IFAD statistics.

Deviations of the area statistics (8,943 ha rice and irrigated crops from EOFI vs. 1,061 ha irrigated land from IFAD for 1996; 11,612 ha rice and irrigated crops from EOFI vs. 5,220 ha irrigated land from IFAD for 2007) result from various factors.

At first, the deviation of the 1996 values is caused by different reference areas. The EOFI area figure covers the entire PHBM-II project area (8,300 km²), and not only the 4 northern communes of Tsivory, Elonty, Mahaly and Marotsiraka (3,233 km²), where most of the irrigation schemes from PHBM phase 1 are located.

Furthermore, mapping of cropland in EOFI has been done with a minimum mapping unit (MMU) of 0.8 ha in scale of 1:100,000, while in PHBM only large irrigation schemes >100 ha (“Petits Périmètres irrigués”) and >10 ha (“Micropérimètres irrigués”) have been addressed. The mapping of smaller patches consequently enlarges the total mapped crop acreage.

Part of the deviation can also be attributed to different data collection methodologies. Terrestrial field measurements as conducted by IFAD for 2007 deliver more accurate results for individual fields, but represent a sampling of the overall irrigated area. The increase of irrigated land as measured by IFAD originates from 71 rehabilitation projects carried out between 1996 and 2008, and is thus not representative for large areas. Some locations inside the PHBM area were severely inaccessible[4] leading to an "*insufficient coverage of villages outside the main towns*"[5]. On the other hand, remotely sensed satellite imagery provides large-scale, blanket coverage over the entire PHBM area.

Finally, the interpretation of the resulting statistics must also take into account the reliability/accuracy of the produced land cover maps, where areas smaller than 0.8 ha (MMU) were not considered. Overall accuracies are slightly over 80%, rice has been detected with 80-85%, rain-fed crops with 70-75%, and irrigated crops with 60-70%.

The differentiation of rice from other irrigated or rainfed crops is not always clear without ambiguity due to the lack of multi-temporal / multi-polarisation satellite radar data and would require better ground-truthing data availability.

Some additional issues were raised by UN-IFAD in order to ensure a successful uptake of the products by local stakeholders, such as the distribution of high-quality hardcopy maps, non-technical product documentation and format compatibility issues.

Feedback from external reviewers

In total 6 review reports from external experts have been provided in addition to the assessment elaborated by UN-IFAD. The reviewers generally confirm the added value of EO derived information due to its synoptic character and the potential for standardized and repeatable monitoring of crop acreage over large areas. One review report written by B. FERGUSON, an external consultant from the University of East Anglia, UK, criticizes that *"the level of accuracy of the GIS analysis of the available satellite imagery seems insufficient to meet the needs of good quality monitoring of crop acreage. It seems that this is most likely due to the relatively low resolution of the imagery used, and the spatial and temporal complexity of the agricultural systems of the high Mandrare Valley*."

In this context it is important to point out that the application of EO satellite imagery for land cover mapping always constitutes a trade-off between available resolution and budget (the higher the resolution, the higher the cost for image data acquisition and mapping) and required detail of the resulting information. It has been shown with this service trial that the service requirements laid down in the initial Service Review phase could be achieved with the available optical and SAR imagery (resolution 10-30 m) in terms of geometric (MMU 0.8 ha) and thematic accuracies (>80%).

Statistics on areas under agricultural production and associated changes over time can be inferred with a clearly defined level of reliability, based on standardized and repeatable information retrieval methods over large areas and acceptable cost. High resolution EO archive imagery even offers the advantage to perform historic monitoring back to the 1980s.

[4] http://www.ifad.org/evaluation/public_html/eksyst/doc/prj/region/pf/madagascar/mg_376.htm
[5] http://www.ifad.org/evaluation/public_html/eksyst/doc/agreement/pf/madagascar_376.htm

Nevertheless, we agree that achievable accuracies and thematic differentiation of various crop types could even be enhanced if the satellite data coverage could be improved. This must always be combined with a strong ground-truthing component and local field work. In this service trial, satellite data coverage unfortunately was far from being optimal (missing multi-temporal / multi-polarisation radar data; large heterogeneity of acquisition dates in- and outside of sowing/growing period of crops) and availability of local field data was limited.

Imagery from the very high resolution domain (<5 m) would be beneficial in terms of local spatial detail (e.g. capturing of small fields and small vegetation patches), but such data are more expensive and do not allow short update intervals over thousands of sqkm. Moreover, very high resolution data are only available since the early 2000s.

FERGUSON further states *“that the data produced are not useful at all for understanding the real trends in agricultural crop acreages”* and *“are not helpful in understanding the real impacts of the 70+ site specific interventions undertaken by FIDA in the high Mandrare”*.

The focus of the service trial was on the observation of status and trends of crop acreages in regional scale, with emphasis on rice fields. The EOFI products therefore provide maps and statistics of stocks and changes of land cover with a known level of reliability for regional monitoring, but are not designed to identify rotation cycles of different crop types (rice, maize, cassava, sorghum etc.) within a year or to assess to which degree individual irrigation schemes are operational or not.

Local site-specific evaluation of small-scale land cover changes in short time intervals (several months) and impact analysis of IFAD interventions would require a different monitoring system employing multi-temporal very high resolution imagery (<5 m) and intensive collaboration with local experts on-site.

FERGUSON also points out that *“the levels of accuracy seem too low, especially considering the relatively small percentage changes to some land categories which are being measured”.*

The service trial specifications called for a minimum overall thematic accuracy of 80% and class-specific accuracies in the range of at least 70–90%. EOFI proved that such requirements can be successfully fulfilled by EO image analysis employing a cost-effective, ready-to-use operational processing chain. All land cover change statistics have been always reported in conjunction with applicable accuracy levels.

In case of evolving user requirements (higher accuracy, more classes, larger scale) a more complete and higher resolution EO image coverage (multi-temporal optical and SAR data) can be established and the processing chain can be tailored towards higher quality output. This however is subject to a higher cost for data acquisition and analysis.

Conclusion of utility assessment for UN-IFAD projects

IFAD considers the EOFI products of service trial 1 important to the AROPA project in the following ways:

- Strengthening Policy Making in Agriculture

"First and foremost, ***Earth Observation will enable effective comparison to ascertain whether farm sizes have dwindled, remained stagnant or have increased*** *since the culmination of IFAD's funding within the agricultural sector of Madagascar in 1979. This will ultimately* ***serve as the basis upon which policy makers can impinge on prospects for a sustainable agricultural development and poverty eradication in Madagascar****.*

When crop acreage is known and proper tools are available, the activities of pests can be monitored and forecast or yield estimates made for a desired crop variety. From this, ***an assessment of expected income from the agricultural and its overall contribution to the countries' economy in terms of gross domestic product (GDP) can be rendered possible****."*

- Comprehensive products and services

"Earth observation data presented in a GIS-based analytical data processing and visualization through charts and maps are an ***illustrative and easy-to-understand means of presenting complicated calculations and forecasts to policy makers, technical advisers and most especially to ordinary farmers****. Worthy of note is the fact that thanks to IFAD's literacy programme, more than 8,000 local farmers[6] have become literate and shall be able to interpret the maps and charts on crop acreage that shall be produced under the current service trial for Mandrare region.* ***Crop acreage maps shall thus portray the state of agricultural production hence could well serve as a platform for agricultural land consolidation and the formation of cooperatives.****"*

Attention must however be paid to the accuracy of EO products and the identification of land use classes

"Difficulties in discriminating between crop categories might create confusion and misunderstanding. For example rice versus rain fed crops versus irrigated crops versus grassland. In some cases, users of the product might be misinformed in cases where one land use class has been misinterpreted and taken for the other. The accuracy of most of the land cover classes is 80%. There is therefore a 20% probability/likely-hood for an error to occur when comparing real ground information with data presented on EO products."

[6] http://www.capfida.mg/site/spip.php?article185

4.2 Recommendations for future improvement

In order to ensure the sustainability of the EO service and further promote the utilization of such products for the monitoring and management of UN-IFAD projects such as PHBM/AROPA, a series of recommendations has been elaborated.

The recommendations comprise of those

- to improve current EO services as well as
- to identify new and exciting fields for future EO service evolution.

4.2.1 Improvement of current EO service

- <u>Synchronizing EO data acquisitions and crop acreage assessments</u>

The procurement of the right quality of satellite scenes over the ideal time window is indispensable for the provision of high-quality Earth Observation products and services. Sub-optimal data acquisition (in terms of resolution and acquisition date) has a negative impact on the thematic accuracies. For future application, there is the need for effective timing of future crop acreage assessments to coincide with a season that provides for the acquisition of the best satellite scenes possible.

- <u>Establishing a periodic monitoring scheme</u>

Depending on the availability of resources, the AROPA project team will need to carry out periodic assessment (for example every 2 years) to monitor the change of crop acreage and yields over time. Such comparisons serve as a guide to ascertain the necessity of terminating, restructuring or continuing investments within the project area.

- <u>Enhancing information content of EO information products</u>

IFAD suggests for future projects to improve the spatial resolution to 5 m. This is in line with the recommendation of FERGUSON, who advocates for a *“scaling down of such monitoring activities to improve accuracy”*. Besides the improvement of spatial detail (which is with an MMU of <1 ha already quite high for regional scale applications), another aspect is to extend the thematic content of the products by adding more thematic classes (e.g. separation of different rainfed or irrigated crops). This, however, can only be realized by employing higher resolution, multi-temporal SAR and optical imagery satellite data and extensive work in the field, leading to a higher demand for personnel and budgetary resources.

Additional data like up-to-date (digital) topo-graphic maps, digital elevation/terrain models and accurate vector data (e.g. roads, water bodies, urban zones, POI) can optimize the analysis workflow and the accuracy of the resulting products considerably.

- Linking regional monitoring with localised site impact assessments

Both, the monitoring of regional impacts of investments and of localized site-specific impacts of agricultural infrastructure investments shall be fostered in a combined approach. FERGUSON describes a two-tier approach to monitor changes in crop acreages:

1. **regional monitoring** examining regional trends in crop acreages and
2. **local monitoring** of sites where irrigation infrastructure was installed by IFAD.

The latter would require very detailed mapping by the combination of satellite imagery and extensive ground truthing (including GPS-based mapping, photographs and basic topographic mapping). The utilization of very high resolution satellite data is recommended to monitor local crop acreage changes, otherwise there would be the risk that accuracy levels undermine the utility of the EO products.

In addition to mere land cover mapping, the regional monitoring scheme would also need to *"incorporate the agriculture related infrastructures directly invested in by FIDA as well as the more indirect impacts on regional agriculture of improving access to markets (road improvements), seed storage, seed varieties, agricultural techniques etc., which FIDA also invested in."*

FERGUSON concludes, that *"without incorporating such a grounded approach to monitoring, the use of satellite imagery becomes an exercise in producing what seem like attractive, colourful maps – but which in reality are potentially disinformation rather than factual information about the agricultural trends in the region due to the levels of accuracy."*

- Ensuring access to EO information products

It has been noted that all digital products need to be provided in formats compatible to commonly used software packages (e.g. ArcView GIS, ArcGIS). In addition, hands-on information material (e.g. hardcopy maps, non-technical product summaries) is needed to attract a wide circle of users and also experts in the field.
Utilization of the products by local stakeholders also requires capacity building in terms of hard-/software and expertise regarding the correct interpretation and usage of such products.

- Sustaining support from local stakeholders

FERGUSON recommends intensifying the level of local support by *"establishing and funding a network of agricultural extension agents"*, who are in charge of providing ongoing support for agricultural activities in the areas of intervention. Such a network could support the EO product generation by acquiring ground-truthing information.

4.2.2 New fields for future EO service evolution

EOFI service trial #1 has targeted the demonstration and validation of an EO service for mapping crop acreage and deriving area change statistics over a period of almost 15 years.

As an extension to the specifications of this service trial, IFAD has identified new fields for EO applications within the AROPA project area. IFAD states, that "*in the phase of increasing threat from drought and the deleterious consequences that come with it, such as desertification, a cost-efficient area assessment methodology providing* ***early estimations of the quantity of food crops (tonnage)*** *that can be harvested over a given agricultural land during each harvest season shall be of great importance."*

Future EO services should also aim at **land suitability assessment mapping**. This will increase productivity and sustainability through the application of precision agricultural practices (InforCom Project, 2004[7]). It is in the interest of each farmer to optimize the harvest and earn the highest yield/profit margin per hectare of cultivated land.

The ESA funded project Global Monitoring for Food Security project is developing an EO based service portfolio for food security assessments and drought early warning services. In this context, GeoVille is operationally providing Soil Water Index (SWI) products for entire Africa on a daily basis.

Such crop yield and land suitability assessments would further support the AROPA project and the Malagasy Ministry of Agriculture in their efforts towards poverty eradication and food self-sufficiency.

As a conclusion, the use of EO information shall be continued. IFAD confirms the *"need for regular consultation and update of EO information".* It will be important to foster a broad dissemination of the service trial results as a blue print, and to spur further investigations with regard to rural food crises and poverty within the AROPA project area and beyond.

[7] InforCom Project 2004: Information and Communications for Rural Communities Project Annual Report.

4.3 Concluding remarks and outlook

The final section of this report aims at providing a summary of the achievements and observed bottlenecks of the project from the perspective of the service provider, as well as an outlook towards a follow-up and upscaling of this EOFI service trial.

What went well?

- GeoVille highly appreciates the active involvement of UN-IFAD and ESA at any stage of the project. UN-IFAD provided a remarkably detailed service assessment, which now forms the basis for a better understanding of their information requirements and to offer a sustainable and fit-for-purpose EO service in the long run.
- We especially value all comments from the external reviewers. Although some comments from local experts (e.g. on the accuracy of the products for local monitoring of crop acreage) may not sound too positive at first glance, we acknowledge those recommendations as very constructive and legitimate.
- EO proved to be a viable tool for monitoring of crop acreage and other land cover types in a highly complex environment. The technical requirements outlined in the Statement of Work and refined at the beginning of the project could be achieved despite a rather poor satellite data coverage and limited availability of local ground-truthing data for calibration and validation.
- We believe that EOFI has paved the way for a good mutual understanding with UN-IFAD on what can be observed from space. Yet, for a roll-out of the service there is still the need to fine-tune the service specifications and precisely define what type of land cover features shall be mapped in what way.

What could have gone better?

- The service trial was designed to be a limited activity. However, as the reviewers' comments make clear, the low-cost approach delivers products that represent a "design-to-budget" and not necessarily a "fit-for-purpose", e.g. in terms of accuracy and thematic content. In other words: To fulfil the requirements and success criteria laid down in the SoW does not necessarily mean to satisfy the user.
- Demonstration of the EO capabilities suffered from a poor satellite data coverage, as no multi-temporal / multi-polarisation radar data were available (single intensity imagery does not allow for unambiguous delineation of the features of interest). This could be partly compensated by optical satellite imagery. However, multi-temporal assessments were deteriorated due to largely different acquisition dates from dry and wet seasons.
- It became obvious in the course of the project that actual requirements of UN-IFAD at least partly go beyond the perimeter of this initial service trial. An effective monitoring of IFAD interventions, i.e. the construction or rehabilitation of irrigation schemes, clearly requires a different monitoring scheme. We consider the two-tier approach suggested by FERGUSON as a reasonable way forward for effective monitoring of IFAD investments: area-wide, recurring

monitoring of land cover changes in regional scale with high resolution satellite data (as demonstrated within this trial) coupled with localised site-specific observations of irrigation schemes employing very high resolution data.

How can the service be upscaled?

- We strongly recommend to take up the momentum initiated with this service trial and set-up a follow-up activity that carries forward the successful elements of the trial and – most importantly – provides a sufficient financial framework for service evolution, including the procurement of data which are fit-for-purpose.
- Financial resources must allow
    - to ensure a more complete (i.e. multi-temporal / multi-polarisation SAR data complemented with optical imagery) and higher resolution (up to 5 m) satellite data coverage
    - to carry out on-site field work and establish better access to in-situ information
    - to continue and intensify supporting actions from UN-IFAD and local stakeholders for periodic monitoring
- Multi-temporal inventories shall follow the two-tier approach:
    - Regional monitoring utilizing area-wide coverages of high resolution SAR and optical data with up to 5 m resolution (at least for agricultural areas), supported by in-situ data and field work
    - Localised site-specific monitoring employing very high resolution imagery with 1m resolution, with intensive integration of in-situ data and field work

Annex A. References

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Annex B. Lists of Figures, Tables and Acronyms

Annex B.1 List of Figures

Annex B.2 List of Tables

Annex B.3 List of Acronyms

AROPA	Projet d'appui au Renforcement des Organisations Professionnelles et aux Services Agricoles
COSOP	Country Strategic Opportunities Programme
EC GMES	European Commission - The Global Monitoring for Environment and Security
EO	Earth Observation
EOFI	Earth Observation for International Financial Institutions
ESA	European Space Agency
FIDA	Fonds international de développement agricole (engl. IFAD)
FR	Final Report
GDP	Gross Domestic Product
GIS	Geographic Information System
IDA	International Development Organization
IFI	International Financial Institutions
INSPIRE	Infrastructure for Spatial Information in the European Community
KO	Project Kick-Off
LC	Land Cover
LU	Land Use
MetOp ASCAT	Meteorological Operational satellite - Advanced Scatterometer
MMU	Minimum Mapping Unit
PHBM	Projet Haut Basin du Mandrare
SAR	Synthetic-aperture radar
SoW	Statement of Work
SWI	Soil Water Index
UN-IFAD	UN International Fund for Agricultural Development
VHR	Very High Resolution