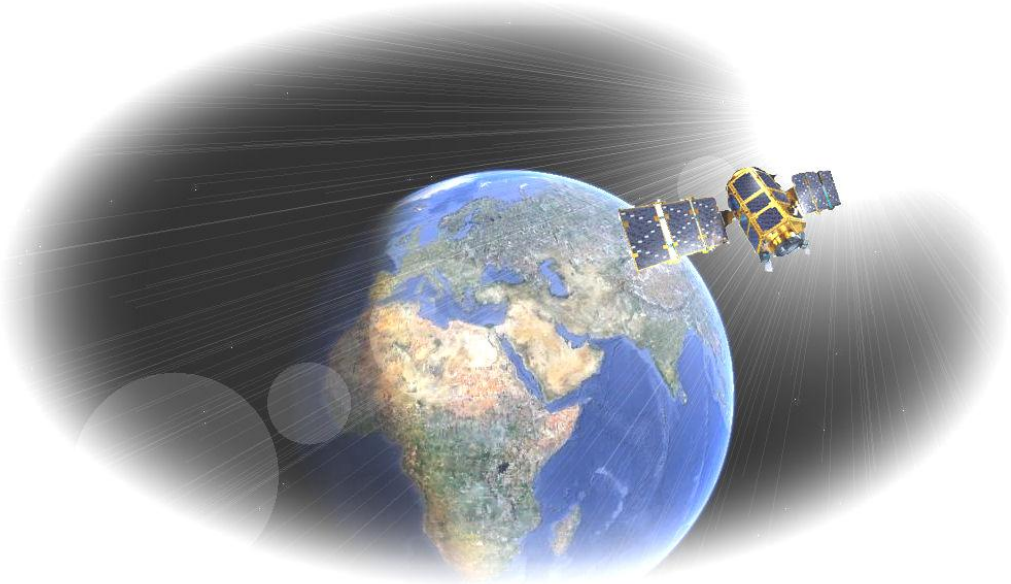
Service Utility Report
(SUR)

EOFI

TRIAL 3



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Colophon

Service Utility Report

EOFI
'EO for International Financial Institutions'
TRIAL 3

Version 01

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1 Scope of document

The present document “EO for IFI – Service Trial 3 – Service Utility Report” provides an assessment of the results of the provision of a satellite data based service in the field of land tenure mapping. The Service is based on Kompsat-2 satellite data and is comprised out of a georectified and colour corrected image mosaic.

Feedback has been sought from the core users on the subject of: utility of the service and products, recommendations for improvement, complaints, problems and their resolution, and the anticipated benefits. Input has been received from IFAD, the PROSPERER project, and from the Responsible for the Cartography of the Haute Matsiatra region.

2 EO service provision

Service trial 3 aimed at demonstrating the utility of currently available Earth Observation (EO) information services to support the monitoring of UN International Fund for Agricultural Development (UN-IFAD) funded projects and those of other international financial institutions. Within service trial 3, the monitoring has been done to develop a Local Land Occupation Plan (PLOF - Plan Local d’Occupation Foncière), capable of facilitating the process of the acquisition of land titles by local farmers in Madagascar.

More detailed, the EO products delivered under this service trial are Very High Resolution Satellite Images (1m resolution at nadir) for the support of current land reform programme (facilitating the issuance of land certificates) in Madagascar.

The products, and the corresponding operational documentation (including html file), have been supplied to ESA and IFAD, IFAD has further distributed the data to local users. The service has been reviewed based on these delivered products which consisted of both analogue as digital data and documentation.

2.1 Utilization of the service

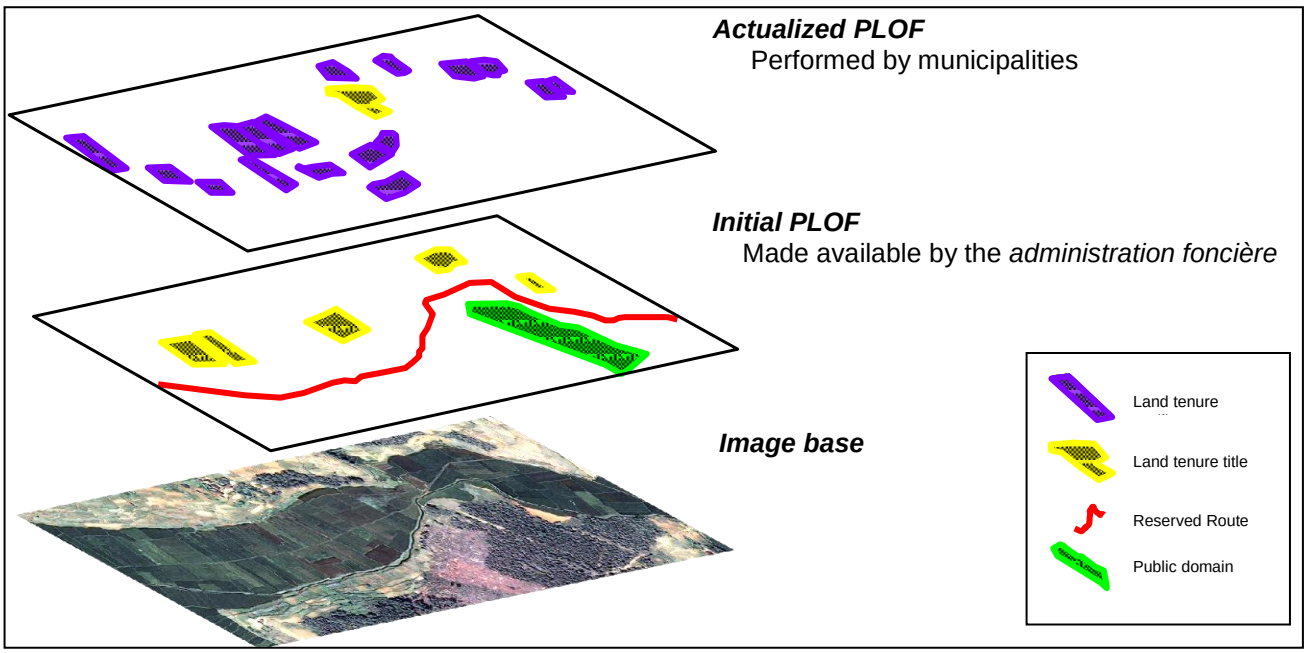
The new guideline for land tenure (politique foncière) is to start a process of decentralization of land management. Eventually, two levels of land management will be realized in parallel:

- The *administration foncière* is responsible for guaranteeing the private property titled through the regional land offices
- Municipalities are given responsibility for managing non-titled private property.

The transfer of part of the jurisdiction from regional offices towards communal offices, requires a sharing of information between the two levels of land management. The Local Land Occupation Plan (PLOF - Plan Local d’Occupation Foncière) is designed to become the tool that will allow the alignment of the two levels of land management. The development of the PLOF occurs in 2 stages:

i. Constitution of "Initial PLOF" in which they record information held by the land tenure offices on the land rights already established in a specified district
ii. Gradual update of the PLOF by the municipality and new registrations by land tenure services

The management of the PLOF by the municipal land tenure office comes into place from the time the administration foncière returns the “initial PLOF” to the municipal land tenure office. The "initial PLOF” is considered completed when all the titled lands, as shown on the plan kept by the surveying services, are carried over to the “image base – fonds image”.



Making an "Initial PLOF" in the context of a modernized land tenure office: the preconditions:

- Provision of an “image base” (orthophoto, digital satellite image). This image database will be used as a visual basis for the delineation of titled land parcels, dependencies in the public domain, and areas with specific statutes.
- Provision of data on land ownership, alphanumeric or on paper.
- Capacity building: Because the responsibility of preparing the initial PLOF returns to the regional land tenure offices, it is necessary to strengthen the skills of agents. The development of an initial PLOF will preferably be delegated to specialised operators, but the land tenure officers will always be required to supervise the procedures and final products.
- Territorial delimitation using satellite imagery.

The delivered product / service has been reviewed especially with this application in mind.

A demonstration of the use of the satellite image mosaic as “image base” for the actual delineation of land parcels has been performed and delivered to the local users, who also based there service review on this demonstration exercise.

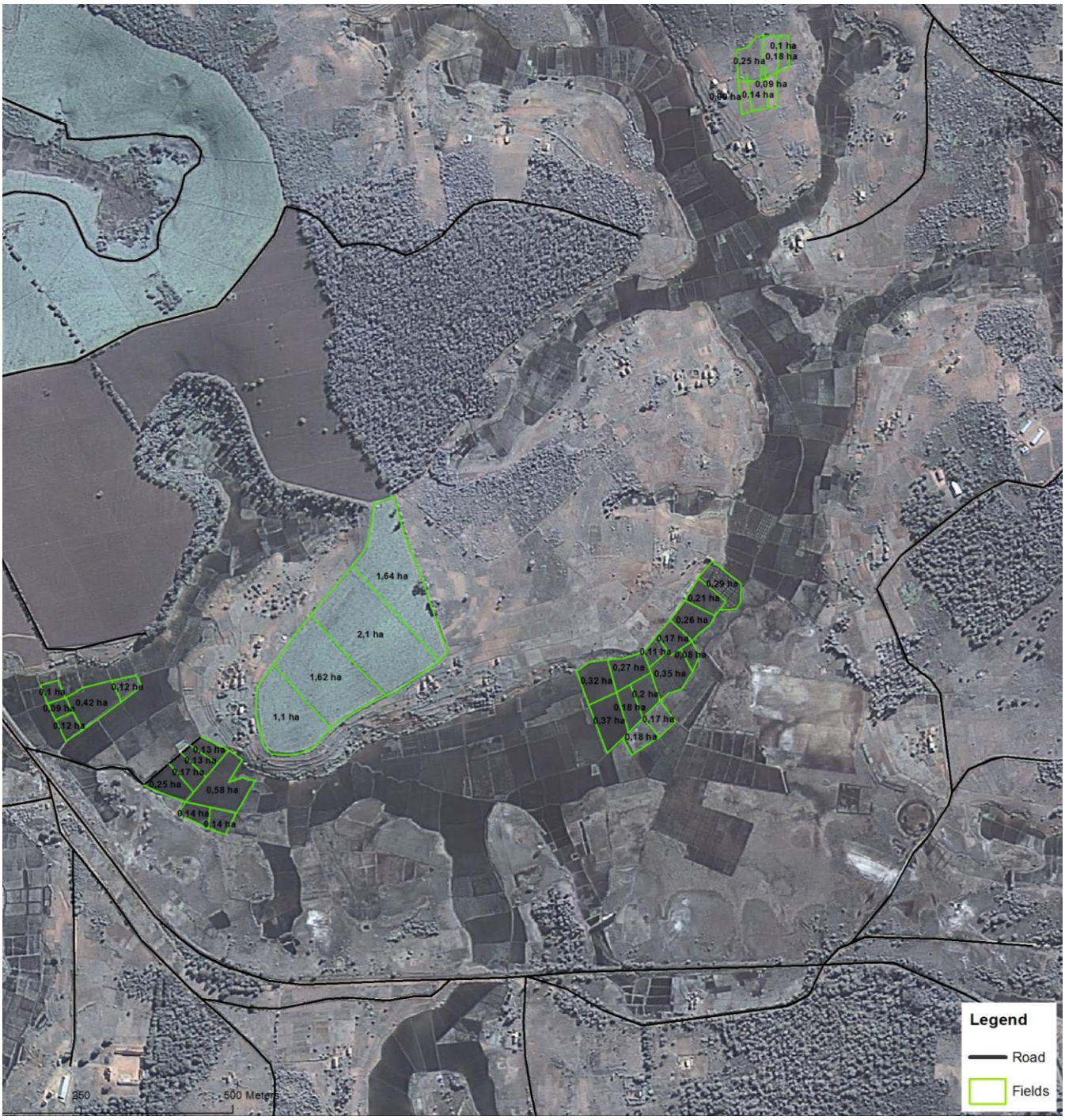


Figure 1: The delineation of single agricultural fields can be performed directly on the image, thereby providing a good estimate of the location and size of a specific field. (scale 1:8.000)

2.2 Encountered issues

As this project has been defined as a “Service Trial”, it is quite logic that some problems have been encountered during the production & delivery of the product. A list of encountered issues is given below, describing the actual problem, the reasons why this problem was encountered, together with possible solutions that could be implied in future projects.

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Some of these production issues were included in the user questionnaire as filled in by IFAD, e.g. colour sharpness and software issues. Remarks regarding the projection system were raised by the Responsible of the Cartography for the Haute Matsiatra Region.

1) Availability of a detailed Digital Elevation Model (DEM)

   No accurate and detailed DEM was available, therefore the freely available ASTER GDEM and SRTM have been combined to create an improved ASTER DEM over the area of interest. This correction included the removal of artefacts, and the comparison of the elevation values of both datasets.

2) Availability of an accurate reference dataset

   Topographic data are provided as scanned 1:100.000 topomaps (GeoTIFF format) in the Laborde Madagascar projection system. The received maps almost cover the complete area of interest. However, the detail and resolution of these maps was insufficient to perform an accurate orthorectification.
   Therefore a set of GPS points were collected by the local user (supported by IFAD). The acquired GPS data have been used to directly georeference the satellite images.

3) Colour differences between satellite images

   As the images have been acquired over a period of almost 4 months, some significant colour differences were visible between the different images (sometimes even within the image). During the production an interactive colour balancing has been performed.
   In future projects, a special focus should lie on the improvement of the colour depth / contrast to improve the image sharpness and colour differences between different image objects.

4) Projection system

   Processing has been performed using the UTM projection system as this was a common factor between the different input data (satellite images, DEM, GPS points). Only in a last step the images have been reprojected into the “Laborde approché” projection system. However it is known that this reprojection results in a shift of the images.
   Further thought on a commonly used projection system needs to be performed to guarantee a general acceptance of the products.

5) Image format and size – software compatibility

   Local users have access to the ArcVIEW 3.2 software package, this “older” software leads to some limits regarding the size and format of the data. E.g. ArcView 3.2 can’t handle files larger then 2GB. Therefore the delivered images were clipped per municipality, and if needed a municipality was split into multiple raster files.
   In future projects, it would probably be better to split the complete image in image tiles (e.g. covering 5 km x 5 km each). Together with this an overview can be created showing the location of the tiles (and listing which municipality is covered by which tiles). This should lower the demand on computer power.

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3 Service assessment

In the beginning of the project a list of user requirements was created, also serving as “success criteria”. The different user requirements and the expected / aimed fulfilment of these service / product specifications are summarized in the following table:

User requirement	Required specifications	Expected fulfilment	Remark	Actual product/service
Orthorectified VHR satellite images:				
- Date taken	2009 or later	June – august 2010		June – October 2010
- Resolution	1.5m	1 m		1 m
- Georeferencing	Similar to topomap [1]	Corresponding to Topomap – Landsat GLS	Can be improved using GPS points [2]	Using GPS points (improvement of original satellite location)
- Image mosaic	Homogeneous coverage	Colour balancing will be performed		Homogeneous coverage through colour balancing
Delivery specs: [3]				
- Delivered data format	GeoTIFF	GeoTIFF		GeoTIFF per municipality (compatible with ArcViw 3.2)
- Delivered data medium	Paper + DVD	Paper + DVD		Paper (A3 prints) + DVD
- Metadata	TBD	According to requirements		According to requirements
- Product description	Clear, available in French & English (provided on paper + DVD)	Part of deliverable		Operational documentation & summary (French & English version)

1 To be further specified through further user contacts

2 Collection of GPS points will be coordinated by IFAD – Eurosense will provide an overview + detail of the to be measured locations

3 Delivery specifications will be further negotiated with the local users (PROSPERER project & land tenure offices & National Coorinator PNF)

3.1 Impact and benefits of the service

Traditional land fragmentation for cropping creates a system of land tenure insecurity sometimes resulting in conflicts. Reducing land tenure insecurity is seen as a legitimate role for the state of Madagascar, and often as a cost-effective intervention. Evidence from Asia and Latin America suggests that formalization of land ownership, through registration and titling, can deliver large productivity gains (Hanan & Bart 2005). Present day local context shows the co-existence and overlap between the modern and informer tenure systems especially within the area of focus Haut Matsiatra. According to Hanan & Bart 2005, only about 10% of lands in Madagascar have legal titles.

Direct benefits

Land titling creates a security of tenure and increases investment in land, agricultural productivity, and land values hence an overall improvement of income situation and standard of living. The benefits/utility of land titling under the current UN-IFAD/ESRIN-ESA joint partnership to support the PLOF of Madagascar shall be beneficial because EO products for land tenure support shall give increased assurance, reliability, and collateral security especially to local farmers who for time immemorial have been at conflict with one another and whose level of family income have not fared any better in the phase of current global crises. Other fallouts (indirect) benefits can be seen in the domain of job creation and food security.

Under the current land reform programme, the EO database of PROSPERER project shall render more efficacy and reliability in land titling in terms of time and money. The old Madagascar's land administration system is seen to be time consuming and expensive and let to decreasing production amongst farming population.

Greater transferability is to be ensured through the current EO trials and this shall go a long way to enhance the return on investment, improves allocation efficiency amongst farming households and finally it shall put land in the hands of those who value it most. In the case of sale of land to another farmer, the title shall serve as a concrete prove to the buyer that the land actually belongs to the seller. This shall serve to reduce conflicts which could sometimes result from double selling as eminent in old land administration systems in Africa.

Titling reduces the risk of land expropriation and gives to the owner of the land security of tenure because a titled deed carries with it a legal guarantee of ownership over a given parcel of land. Land titles, in other words, are valuable to farmers even if they do not appreciably enhance investment in land. A land title does not only protect and give security to a local farmer against powerful and influential elites, but it also raises land value and hence land productivity; other factors of production (labour, capital and entrepreneurship) being equal.

The old system of land titling has been considered to be obsolete and void of any comprehensive data base management system. It can thus be seen as a medium through which influential people could easily corrupt their way through with factitious titles and deprive peasant farmers from their ancestral lands. The old system therefore had no reference document such as does the ongoing land tenure support programme where the authenticity of any land title can always be checked through an auto-rectification process using high resolution satellite images and digital information (data) stored on the computer.

Using this present system being introduced, old and out-of-date land titles shall be transposed and incorporated within the system and used as bench marks to perform future updates. In this way therefore, old titles acquired through the old systems shall still confer considerable protection to their owners since land parcels shall be mapped through a participatory process involving the local

community; village chiefs and land tenure offices. To this effect therefore, the boundary limits of each title holders land shall be agreed upon.

The modern titling system shall be easier to exploit more than the old system of land titling since the inheritance of a title will transcend from one generation to the other and to a greater extent shall have to bear the same family name. Furthermore, titled deed shall be registered in the land administration office and shall serve as a reference point for the issue of new land titles. It shall thus be very difficult for a new land title to be issued for land that had already had a land title.

Titled land serves as collateral to farmers when they go to borrow from banks/cooperatives when they are in need of money to buy farm inputs such as pesticides, fertilizers and improved seeds.

Indirect benefits

Current land titling efforts shall create new employment within the land and survey department and it shall also create the need to train new labour force to employ in the domain of land information management. Furthermore, through a spill over effect, new jobs shall be created within agro-industries that might in the long run be established to process excess agricultural produce.

Effective land provision through the PLOF scheme shall be seen as a prerequisite towards attaining sustainable food security and poverty eradication. PLOF has the possibility of promoting land consolidation and strengthen food security prospects in the long term.

Disadvantages/limitations

Earth Observation satellite images of high resolution might be too expensive to purchase. This shall have a bearing on the PLOF's scaling up and sustainability.

Formal, individual legal titles can be expensive and may benefit elite members of society more than poor rural people.

Summarized

Direct benefits:

- Cuts cost
- Reduce time
- Reliability
- Assurance
- Collateral security

Indirect benefits:

- Employment
- Food security

Disadvantage:

- Expensive earth observation data
- Benefits elite members of the society

The specific added value of EO data in the modern land titling system

The benefits as described above are mainly benefits coming forward from the implementation of a new land titling system. However, more specific, how does EO data help in implementing this system and what are the extras due to using image data?

Having access to up-to-date geographic information is an absolute prerequisite for the establishment of an objective land tenure system, this in order to create the fonds image as defined in the PLOF. Very-high-resolution satellite data has a sufficient level of detail to perform the land tenure mapping, enabling the identification and delineation of land concessions on a very detailed level.

A VHR satellite image can be very useful to identify urban zones, forests, agricultural areas, roads, etc. The delineation of single agricultural fields can be performed directly on the image, thereby providing a good estimate of the location and size of a specific field.

The main benefits of using satellite data is their large area coverage, making extension to large area application feasible. Such a large area coverage also enables the comparison between different regions. Most satellites also provide data in the infra-red range of the image spectrum; this should facilitate the differentiation between vegetation types (agricultural crops).

3.2 Value statements of the users

Following value statements have been extracted from the feedback received:

IFAD:

> *" Under the current land reform programme, the EO database of PROSPERER project shall ender more efficacy and reliability in land titling in terms of time and money. "*
>
> *" The product shall be useful. Reasons being that it is going to facilitate the process of issuing land certificates to farmers and developers within PROSPERER project area. "*
>
> *" The methodology provided can be used by local teams and the html/web pages helps to describe the experiment. "*

ANDRIAMAMPIERIKA Ralainirina Charles - Responsable de la Cartographie de la Région de la Haute Matsiatra

> *« La résolution du spécimen d'image est assez élevée pour permettre la délimitation des parcelles culturales, là ou ces limites ne sont pas assez nettes, le recours aux petits materiels topographiques (GPS, quintuple décamètres et rapporteurs) est préconise. »*
>
> *" The image resolution is sufficiently high for the delineation of agricultural parcels, where such limits are not sharp enough, the use of small topographical material (e.g. GPS) is recommended. "*

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4. Recommendations for future improvements

A set of recommended improvements for future products / services were already shortly described when stating the encountered issues. In this chapter, the potential service improvements are described in a summarized way, this with the aim to come to a service which could be extended / upscaled to larger areas.

Upscaling of the service

Most technical issues encountered during the service trial can be linked to the non-availability of reference data (being DEM, ground control points, projection system). To guarantee a successful upscaling of the service, these issues should be solved. However, as shown in Chapter 2.2 - Encountered issues, most issues can be solved easily. These encountered issues should be tackled in an organized way, thereby guarantying a homogeneous reference (horizontal & vertical) dataset over the area of interest:

- Digital Elevation Model: can be created based on ASTER GDEM & SRTM
- Horizontal references: best is to collect a set of accurate GPS points

The new land titling system is going to put a stop to the old systems of land titling where farmers spend huge sums of money and have to go through a long and complicated procedure to acquire land certificates. This new system is thus more direct, time saving and less costly though the initial investment to set it up is very costly.

Therefore the exercise on the possible upscaling of the service has been performed taking into account not only the technical feasibility, but also the investment needed to create an image base. Some considerations have to be made in order to come to a detailed cost estimation:

Image resolution

The service trial was elaborated using very high resolution satellite data with a resolution of 1m. This resolution made it feasible to distinguish most field boundaries (especially easy in irrigated rice fields), however for very small fields or adjacent parcels with a similar crop, this was difficult.

The effect of using imagery with a slightly lower resolution (e.g. Spot5 2.5m) would only have a minor effect on the delineation of the agricultural parcels. Clearly identifiable parcels that can be easily identified using the 1m data, would pose no problem to delineate at a 2.5m resolution image. Off course the minimum size of a parcel that can be mapped would raise, however not dramatically. Using even lower resolutions (e.g. 5m) is not recommended as parcel delineation becomes almost impossible (at least in the area of the Service Trial).

The applicability of these data for land tenure mapping can be estimated based on the image examples below (images at a scale of 1:3.000).

Image size

In general, the higher the image resolution, the smaller the area covered by one (1) image. E.g. Kompsat2 images have a coverage of 15 km x 15 km (so 225 km²), a Spot5 image covers an area of 3.600 km², this is a difference with a factor 16.

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This higher image size makes that these sensors are better suited to cover large areas, whereas the coverage of e.g the Haute Matsiatra region with VHR data (e.g. Kompsat2) would probably not be feasible within 1 year /season.

Off course, the more images required to cover an area, the more images that have to be processed from raw data to an orthorectified image mosaic.

Data cost

Logically, the higher the resolution the higher the price, although this is not always true as imagery with a resolution of 1m and better is mostly sold per km², while the slight lower resolution images (e.g Spot5, Formosat) is being sold per scene. For small areas or very irregularly formed areas this rule can not always be applied.

Colour or panchromatic

The service trial was performed using multispectral data, however for the delineation of agricultural parcels a panchromatic image might be sufficient (e.g. in France panchromatic data are used for the delineation of the fields during the agricultural control).

Off course if only panchromatic images are used, there is no need for pan-sharpening, which results in a reduction of the processing costs.

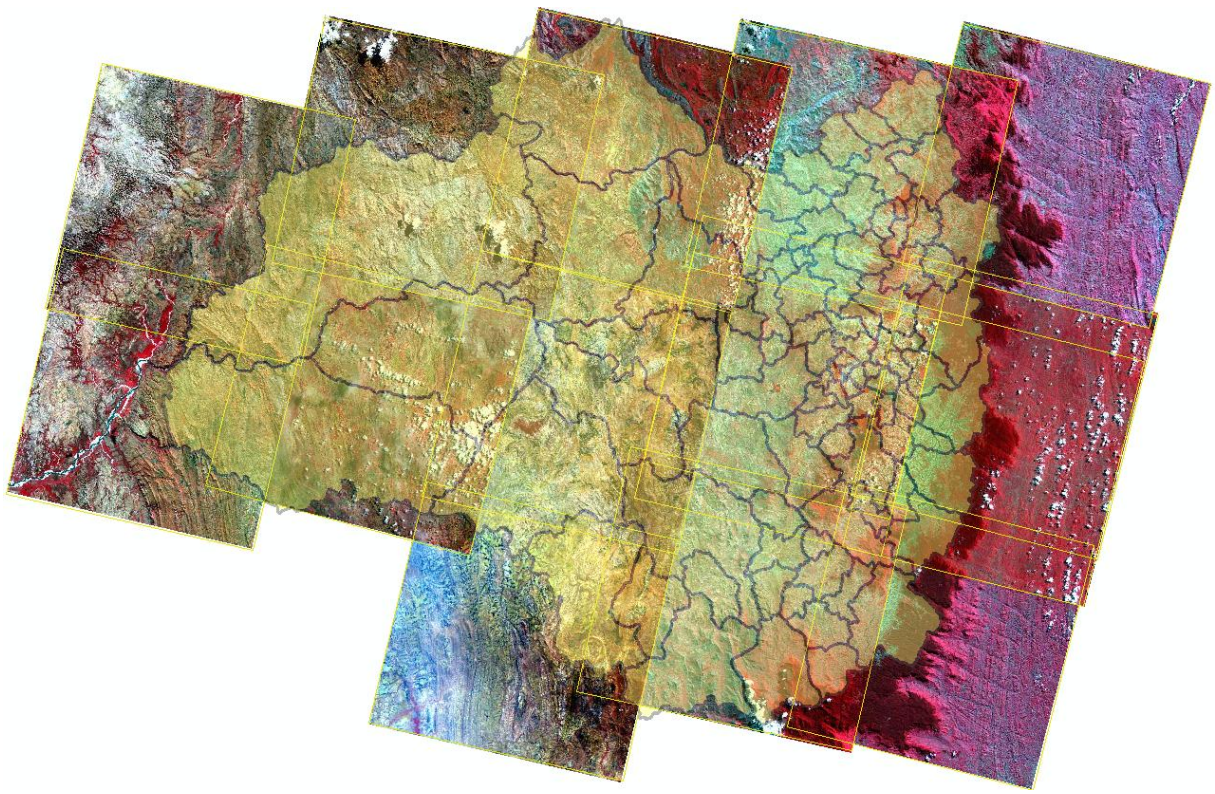

Figure 2: SPOT5 2.5m coverage (2010) over the Haute Matsiatra region

Figure 3: 1m image (original Kompsat2 data)

Figure 4: 2.5m image (resampled Kompsat2 data)

Figure 5: 5m (resampled Kompsat2 data)

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Specific cost calculation

Different options are being proposed, cost calculations include image and production costs only, with the assumption that a DEM and GPS points are available. Cost estimations have been made to cover the complete Haute Matsiatra region (ca 21.000 km²) considering archive data are available.

Option 1: Kompsat-2 data (1m - colour)

- Data cost	21.000 km² @ $ 14 / km²	€ 214.200
- Pan-sharpening	ca 55 images @ € 150 / scene	€ 8.250
- Ortho-rectification	ca 55 images @ € 375 / scene	€ 20.625
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Total image + production cost		€ 243.075

Option 2: Kompsat-2 data (1m - panchromatic)

- Data cost	21.000 km² @ $ 12 / km²	€ 183.540
- Ortho-rectification	ca 55 images @ € 375 / scene	€ 20.625
---		---
Total image + production cost		€ 204.165

Option 3: Spot5 data (2.5m colour)

- Data cost	13 images @ € 8.100 /scene	€ 105.300
- Pan-sharpening	13 images @ € 150 / scene	€ 1.950
- Ortho-rectification	13 images @ € 375 / scene	€ 4.875
---		---
Total image + production cost		€ 112.125

Option 4: Spot5 data (2.5m panchromatic)

- Data cost	13 images @ € 5.400 /scene	€ 70.200
- Ortho-rectification	13 images @ € 375 / scene	€ 4.875
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Total image + production cost		€ 75.075

* Note that the cost estimation above are solely an informative information and do not bind EUROSENSE in any way.

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Extra potential products / services

As shown above, the main cost of creating an “image base” for land tenure mapping is the purchase of the image data. However, these images can be put to other uses as well, some ideas are given below.

Creation of land use / land cover maps

(V)HR optical satellite data are very well suited to create land cover maps identifying e.g. agricultural areas, forested area, villages, etc. This can be an important input for an assessment on the distribution of resources, a population density map, etc. Agricultural land can easily be classified as irrigated or non-irrigated based on the images.

Mapping of a road network

These satellite images can serve as the primary dataset for the creation of a road map.

Land value assessment

The images can be used to interpret an agricultural parcel and its surroundings to estimate the parcels value without the necessity to travel.

The main benefit of a satellite image base is that all above mentioned derived products will be based on a uniform dataset, thereby resulting in a homogeneous product.

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