PANDA MITI KIBIASHARA

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REVIEW OF GEOSPATIAL RESOURCES AND FOREST INFORMATION SYSTEM (FIS) SOLUTIONS FOR THE PRIVATE FORESTRY PROGRAMME

United Republic of Tanzania
MINISTRY OF NATURAL RESOURCES AND TOURISM
Forestry and Beekeeping

FORMIN.FINLAND.FI
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Review of Geospatial Resources and Forest Information System (FIS) Solutions for the Private Forestry Programme

Final Report

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ABBREVIATIONS

DBMS	Database Management System
FBD	Forestry and Beekeeping Division
FDT	The Forestry Development Trust
FIS	Forest Information System
FMIS	Forest Management Information System
GIS	Geographical Information System
GPS	Global Positioning System
ICT	Information and Communication Technologies
IGA	Income Generation Activity
KVTC	Kilombero Valley Teak Company
LGA	Local Government Authority
M&E	Monitoring and evaluation
MIS	Market Information System
MFA	Ministry of Foreign Affairs of Finland
MNRT	Ministry of Natural Resources and Tourism
MoU	Memorandum of Understanding
NAFOBEDA	National Forest and Beekeeping Database
NAFORMA	National Forest Monitoring and Assessment of Tanzania
NCMC	National Carbon Monitoring Centre
NFI	National Forest Inventory
NGO	Non-governmental organization
OS	Open Source
OSP	Outgrower Support Program
PD	Programme Document
PFP	Private Forestry Programme
PLUM	Participatory Land Use Management
PSP	Permanent Sample Plot
RDBM	Relational Database Management
SMEs	Small and medium enterprises
TFS	Tanzania Forest Service
TGA	Tree growers' association
TGIS	Tree-Growing Incentive Scheme
ToR	Terms of Reference
UTU	University of Turku
VLUP	Village Land Use Plan
WCS	Wildlife Conservation Society
WWF	World Wild Fund for Nature
QGIS	Quantum GIS, an open Source GIS Software.

EXECUTIVE SUMMARY

The purpose of this report is to support the Private Forestry Programme (PFP) programme management team and relevant stakeholders in planning of a Forest Information System (FIS) and in planning effective uses of geospatial information for the programme. It describes the current geospatial and other data usage and management processes, presents an overview of existing resources and FIS solutions, and provides recommendations for developing a feasible FIS solution for PFP.

Key findings

Data collection and management

PFP is rapidly scaling up the TGIS, with the aim of establishing 15 000 ha of plantations by 2017. At this stage of the programme, it is essential to focus on well-planned data collection and management procedures. Currently there are no comprehensive instructions for data collection and management.

Available data

There is a lot of geospatial data available for the programme area. Some freely available data, such as the elevation models and the precipitation maps, are currently not utilized. These can provide support in decision making e.g. when planning for the next planting areas. All freely available datasets have been collected as part of this assignment and have been delivered to the PFP. During the next few years, there will be new sources of freely available geospatial data with higher resolution. PFP needs to invest in some critical supplementary data sources to obtain information of the forest plantation baseline, existing land cover and land uses and infrastructure.

Village Land Use Planning

Currently there are major deficiencies in the VLUP process, which decrease the quality and effectiveness of the VLUPs. This has resulted in a situation where the VLUP process is not effectively guiding the use of land in the villages. Although some of the problems are out of the scope of the PFP, there are critical geospatial issues in VLUP, which PFP can substantially improve with their support and expertise.

Development of a FIS for the PFP

The FIS of the PFP will have to handle many distributed geospatial tasks, of which some are not among the core functionalities of conventional FIS solutions. The FIS of the PFP will have to adapt to the changing conditions and demands of the users while efficiently serving the needs of the key beneficiaries of the programme, i.e. the individual tree growers.

The immediate needs for the FIS are related to data management issues, which can be solved with a relatively simple solution. As the plantation forestry and development of the related organizations (TGAs, Apex body, FDT, etc.) are still in early phase, the FIS should be considered as a gradually developing system. At this stage, it is not feasible to invest to a comprehensive commercial FIS solution, but rather start building an Open Source (OS) based system that can be modified and tailored at any time. This will ensure that the system is flexible whenever new requirements arise.

The best way to ensure the buy-in of the FIS users is to allocate adequate resources for initial capacity building and human resources.

Key immediate recommendations

- Review/establish data collection and data management procedures for the programme
- Coordinate and harmonize the data collection and analyses activities with the FDT and other actors and experts in the region

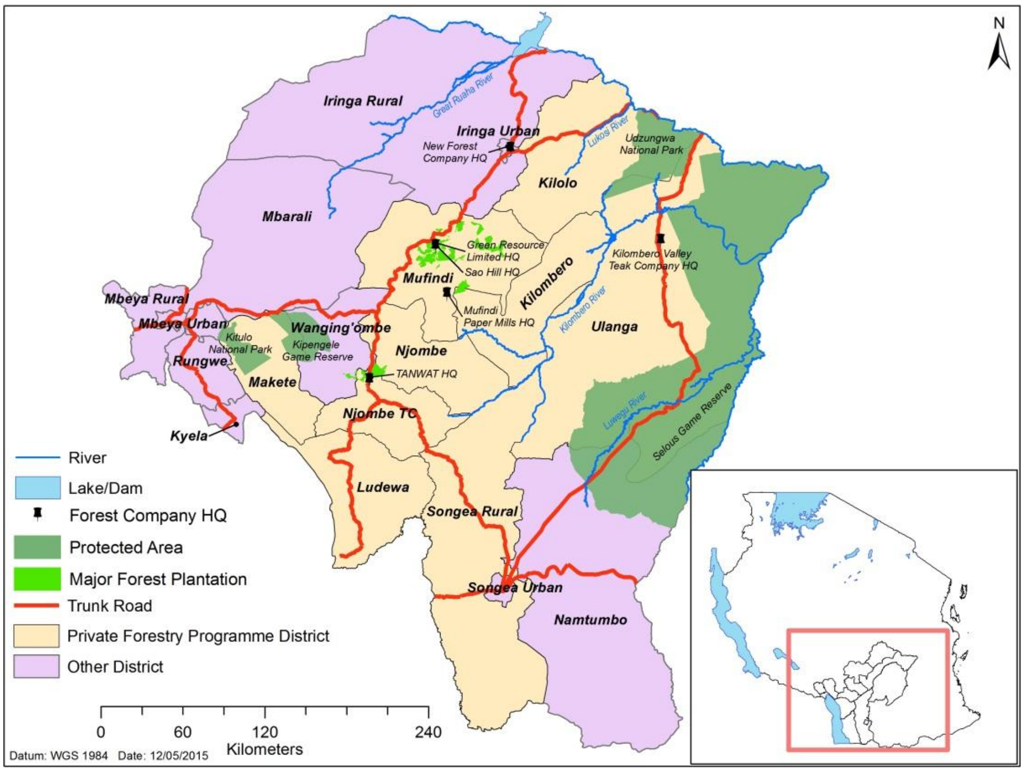
- Initiate the development of the FIS using OS solutions that are flexible and free of charge (draft the ToR)
- Address the geospatial deficiencies in the VLUP process to promote the quality and effectiveness of the VLUPs
- Test the use of existing data for the improved performance of the programme results and produce critical supplementary data needed for the spatial planning and decision-making in the programme
- Lay technical and human resources foundation for the development of a future FIS service, which will serve the needs of the programme, key beneficiaries as well as the other relevant actors of the forestry and natural resources management sector

1. INTRODUCTION

1.1 Private Forestry Programme and the need for a review of geospatial resources and FIS

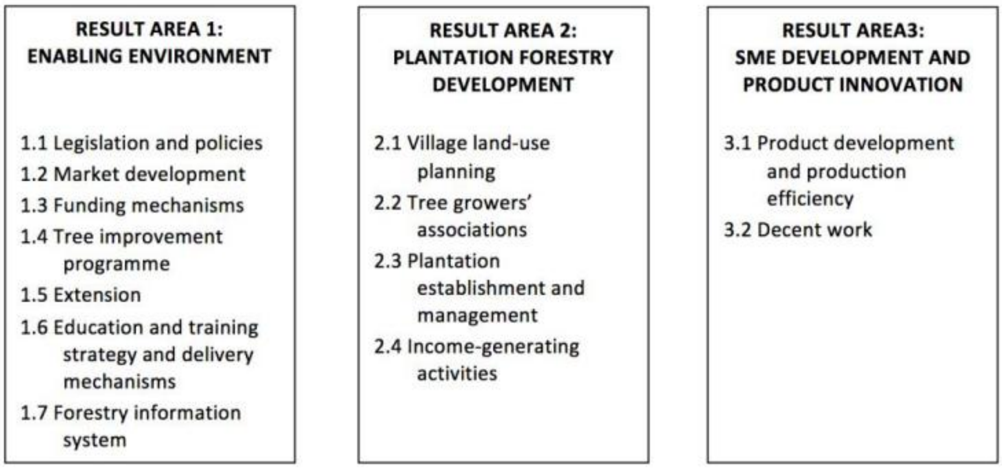
Geospatial resources and solutions are fundamental part of the successful implementation of the Private Forestry Programme (PFP), which operates in the regional of the Southern Highlands in Tanzania (Figure 1). The programme key result areas (their planning, resourcing, budgeting and monitoring) are dependent on the availability and efficient use of spatial information (Figure 2). Much of the data is collect, stored, updated and managed by the programme staff, but many information sources come from external parties and actors in the region and the system is eventually also used by various beneficiaries. As the programme needs to secure the development of geospatial capacities of the actors involved, the training and follow-up of the skills development of the project participants is necessary part of the success of the programme. An operational Forest Information System is a key part of this.

Figure 1 Private Forestry Programme districts



In the Programme Document (PD), FIS development work is linked to Result Area 1, Output 1.7: "Effective and open forestry information system developed for the private forestry value chain, thereby ensuring easy access to all relevant documentation." The PD calls for a FIS which will be web-based and developing it will include assessing needs, developing the system's structure, collecting base data, establishing a system for updating data continuously, and establishing an operational body for FIS.

Figure 2 Programme Result Areas and Outputs



Source: Programme Document, 20.8.2015

The PD also outlines four focus areas to build a GIS/FIS solution for data management of the programme: 1) Geospatial data collection, 2) Organization, storage, management and sharing of spatial data, 3) Data analysis and visualization/communication, and 4) Training. This review provides an overview of the status and outlines the further development needs of the focus areas. The review was necessary before further investments in FIS and geospatial resources are made, and before data infrastructures, training and capacity development are designed on top of the data and information system. Based on the review, the programme will be able to establish a feasible roadmap for the FIS development.

1.2 Objectives of the ToR

This consultancy assignment was focused on the review of the existing geospatial resources and FIS solutions for Private Forestry Programme. The key objective of the assignment is to fill in the gaps of geospatial information and GIS/FIS knowledge for the programme and provide necessary background information related to the role of geospatial information and FIS in the execution of the key programme components.

The objectives of the assignment were to:

- Analyse the programme's needs and requirements for geospatial resources and for the establishment of a FIS
- Collect and review existing geospatial resources (data) from the programme area
- Review different FIS/GIS solutions in relation to PFP core activities and components
- Suggesting practical GIS and solutions for the Village Land Use Planning (VLUP) process
- Assist PFP personnel in the identification of human resources and capacity development of the key FIS/GIS personnel
- Shortlist possible further studies to strengthen the implementation of FIS and
- Provide recommendations for FIS data collection and development

The work was conducted as a team of consultants from the University of Turku (UTU), Niina Käyhkö and Joni Koskinen and Indufor Ltd, Lauri Tamminen. The team leader was Niina Käyhkö. Additional support for the ToR was received from the researchers Nora Fagerholm and Salla Eilola, who were acting as expert in VLUP related solutions.

The consultancy included 60 working days, including a field mission to Njombe by Niina Käyhkö and Lauri Tamminen in August 2015 (10-21.8). Salla Eilola was accompanying the team in Njombe from August 18th to 21st.

2. METHODOLOGY

2.1 Review of the current geospatial practices of PFP

The PD and other background documents were reviewed prior the field mission to study the planned use of geospatial resources in the PFP. We studied the current practices in the field through interviews and group discussions with the key programme staff.

2.2 Review of the available geospatial data covering the programme area

We collected freely available geospatial data sets of the Southern Highlands region from various data providers' web pages and services and evaluated the feasibility of the data for PFP. In the documentation of the data properties, we followed the standard metadata guidelines of geospatial data (ISO 19115:2003, revised ISO 19115-1:2014), but simplified the documentation into the following items: ID, filename, name, description, copyright, date, image, scale/resolution, format, coordinate_system, theme, key, type, spatial_coverage, responsible, history_desc, size, source. The "theme" of the metadata was identified on the basis of INSPIRE recommendations available at: http://inspire.ec.europa.eu/index.cfm/pageid/2/list/7 (Table 1). The current metadata table contains documentation of around 80 geospatial data sets. The metadata is stored at UTU postgres database and the data sets (25 GT) are organised into the thematic folders and stored at UTU and copy handed over to PFP.

Table 1 Description of the documentation of the spatial data sets

Metadata items	What does each item describe?	Important to know
id	running unique number given to each spatial data	The number is following the order of UTU Tanzania postgres database. Thus numbers do not start from 1
name	colloquial file name given for the data	
description	verbal description of the data and its contents-	This column tries to explain what information does the data contain
filename	physical name of the file	the name as it is stored in the folder. (e.g. boundaries.shp)
theme*	what theme/topic does the data describe	INSPIRE directive classification of the themes. See http://inspire.ec.europa.eu/index.cfm/pageid/2/list/7
copyright	who has the ownership of the data?	Institution
date	when was the data produced?	daymonthyear (eg. 07122014). In case of updating or modifications, add two dates. original date and modification date
spatial resolution/ scale	scale as a ratio or as cell size	this is not the print scale, but the scale of the data, if it is known
format	digital format of the file	eg .shp, tif, jpg
coordinate_ system	EPSG number and name of the system	eg. EPSG:21037 - Arc 1960 / UTM zone 37S
type	vector of raster	
spatial_ coverage	site name, area name	true coverage/spatial extent of the data
responsible	who is responsible person and key contact of the data?	Institution/person. Can be the same as the above, but may also be different
history_desc	if the data has been edited or otherwise changed, please tell here	also write who has done the editing and when and why

source	where has the data been obtained	Institution/person

We made operational and technical feasibility assessment for the data sets to facilitate their use for PFP. Operational feasibility concerns information content and spatial and temporal scale and the production date as well as access and availability of the data sets and data processing and analysis possibilities. The technical assessment looks into the data format and coordinate system and data structure, which all influence the way the data sets can be used.

2.3 Review of the existing FIS and GIS software and solutions

The review included a coarse pre-feasibility assessment of the existing FIS and GIS solutions prior to the field mission. This included gathering of basic information on existing systems from the internet and drafting a preliminary list of the most suitable solutions for PFP. During the field mission, the needs of the PFP were analysed together with the local experts and the most relevant FIS solutions were chosen for a more detailed review. These solutions are presented in Chapter 4.1.2.

2.4 Field mission and situation analysis on site

The field mission to Njombe was conducted 10 – 21 August 2015. The objective of the mission was to understand the PFP's needs and requirements for geospatial resources and for the establishment of a FIS. The field mission consisted of workshops, group discussions, and a visit to one of the PFP supported villages. Situational analysis of the VLUP process from community perspective, particularly the challenges and opportunities for GIS solution in improving the VLUP process was also carried out. The data collection was done using focus group discussions and interviews in two villages in Makete district: one village which has gone through VLUP planning process and one village which will be part of testing GIS methods in VLUP process. Based on the initial discussions with the programme staff, the structure of this review was slightly modified to better suit the current needs of PFP.

The timetable and activities of the field mission are presented in Annex 1 and Annex 2.

3. CURRENT SPATIAL DATA MANAGEMENT PRACTICES AT PFP

As of August 2015, PFP has only been operational for less than 2 years, and therefore the data collection, updating and management practices are constantly developing. During 2015, the programme was re-structured, which also had an impact on the working modalities and responsibilities within the programme. The following chapters describe the current spatial data management practices in the PFP.

3.1 Selection and mapping of the villages from the project regions

In the early stages of the project, there was a discussion of the critical environmental thresholds influencing, which areas are suitable for tree planting and growth in rain-fed conditions. It was decided that areas, which receive at least 1 000 mm of rains annually would be suitable. To identify such areas, the project executed a ToR, which resulted with rough suggestions of the target areas for PFP (Anderson 2014). These suggestions have steered the area selection work.

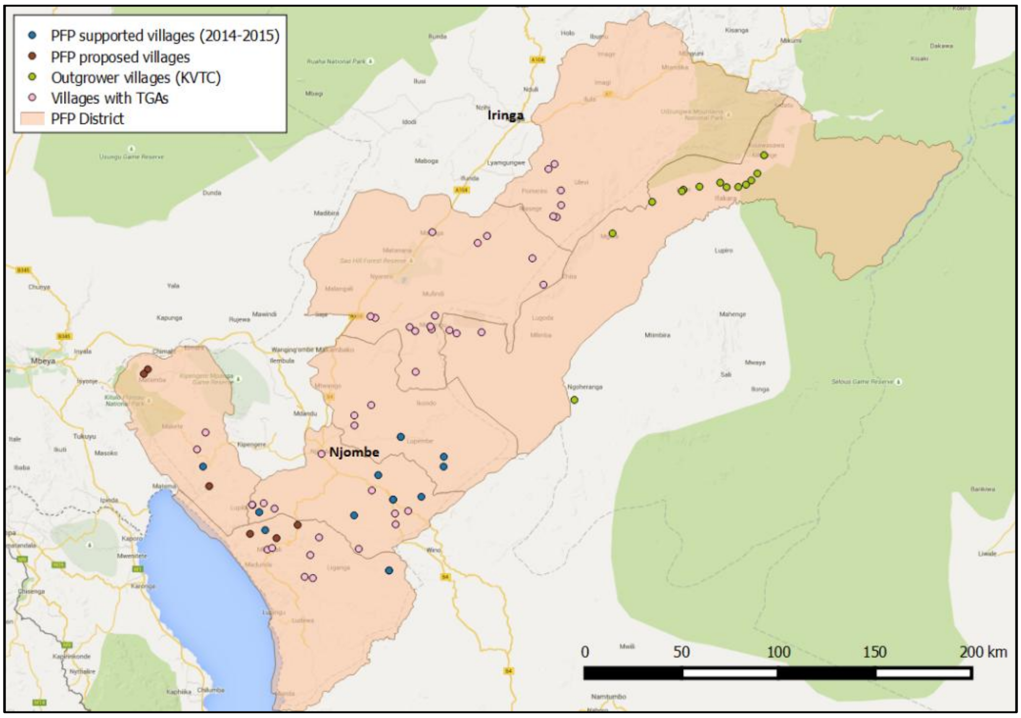
Within the suitable areas, the first practical step in the PFP support for tree planting is the selection of the villages where to operate. This starts by interviewing the Local Government Authorities (LGAs). LGAs have the best knowledge on the local conditions and contacts to the villages. LGAs and the village residents estimate the area available for tree planting as well as confirm the rainfall and other suitability factors for the site selection. Using these criteria, the LGAs provide recommendations for the villages to select, after which the PFP reviews them internally, and selects the villages to support.

PFP has two main criteria on top of the rainfall for the target villages:

1. The working modality through Tree Growers' Association (TGA) and Apex body is accepted in the target villages
2. The area available for new tree planting establishment is more than 200 ha

When the village is selected for the plantation establishment, the VLUP process is initiated with the district teams and PFP team records the location of the villages using a GPS (x,y,z coordinates). The points are taken in the village center, usually in front of the village office. The points are saved as a GIS file, with attributes of the VLUPs and TGAs (Figure 3).

Figure 3 Locations of the PFP supported villages



3.2 Village Land-Use Planning (VLUP)

Village Land use Planning Process is carried out as a collaborative work between districts PLUM teams and PFP. PFP gives financial support to the districts for the preparation of the VLUP and the VLUP directs the establishment of the programme plantation areas in each target village.

VLUP assures that forest plantations of the TGAs are targeted to the areas, which village land committees with the approval of village general assemblies have chosen for tree planting and that the size of the area is sufficiently large for plantation establishment by TGAs. Mapping of the plantations and keeping records of the woodlot owners by PFP and TGAs on the other hand can support the official land registration, which the farmers may choose to do for their own plots.

The overall VLUP process consist of 4 general stages of Preparation, PRA, VLU map production and VLUP & bylaw preparation, each of which is further divided into specific tasks (Figure 4).

Figure 4 Generalized steps of the VLUP process where spatial data and GIS play an important role (Figure: Salla Eilola)

VLUPs allocate land to different uses as determined by the community (agriculture, grazing, forestry, conservation, settlement etc.). The current process of plantation establishment of PFP starts with the village land committee deciding where the plantation area(s) can be established. Once the areas are identified, they are delineated into the Village Land Use Maps and marked as “forest plantation areas”. These plantation areas control the overall location of the TGIS woodlots and their placement in the village. The village land use management committee further decides how the area allocated for plantations is divided between the individuals (in case the allocated land is communal land).

The VLUP process, as indicated in the guidelines, involves preparation of five different map products: village base map, village existing LU sketch map, village land use plan (VLUP) sketch maps and the digital versions of these sketch maps. Sketch maps are hand drawn mental maps of the ways the village residents see the location and extent of the current and planned land uses, infrastructure and landscape features (Figure 5). These maps are made together by the community representatives, although some of the sketch maps may have been drawn by one person as a result of the group discussion.

Figure 5 Example of a sketch map from Mavanga village in Ludewa district.

Currently the sketch maps are not made in any specific cartographic scale. They are drawn on blank paper using marker pens and sometimes sketch maps are first drawn on the sand using rocks and sticks, and then drawn on paper.

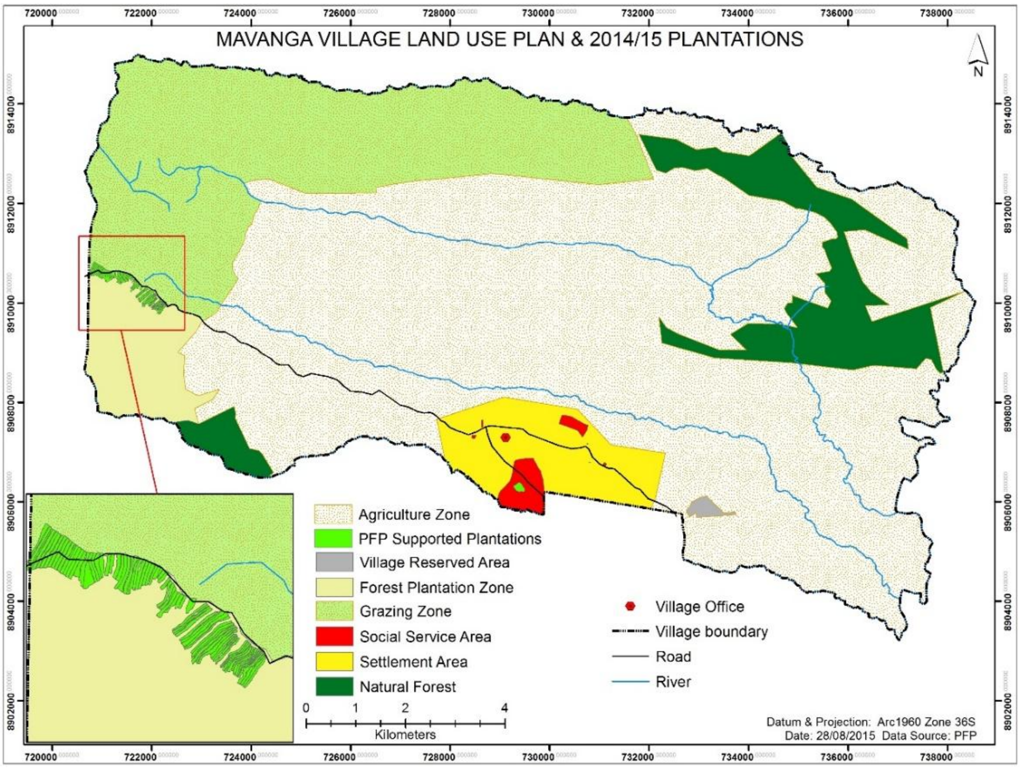
Since the sketch map is guiding the production of the existing village LU map and VLUP map in GIS together with the village base map, the lack of scaling makes the task for the district officers difficult in practice. Furthermore, since there is a severe lack of up-to-date baseline data of topography, roads, settlement areas and land cover, the process of creating a land use map is professionally hampered. Instead of mapping existing land patterns from a decent background image or a map, the PLUM team has to physically map various land uses in the field, including redrawing the village boundaries. This time-consuming work phase is done with GPS devices by foot. However, many sites are not visited due time constraints.

For the village base map, existing LU map and VLUP map production the district officers have in their use GPS devices, topographic maps from 1960s and village boundary data set composed of approved village maps from the National Bureau of Statistics (NBS). The nationally produced village boundary data is not necessarily accurate and thus requires field tracking with representatives of villages for verification. This boundary verification exercise is potentially a cause for boundary disputes between neighbouring villages and may prolong the establishment of VLUP.

The digital/softcopy village base map, existing village LU maps and VLUP maps are prepared at the districts by those district officers (town planner, regional planner), who have skills and software to make the maps. PFP has been providing the districts with computers. There has been some training with respect to using GIS software (QGIS), but currently the district teams seem to prefer using ArcGIS.

The final digital VLUPs (the plan document with the VLUP map) are handed over to PFP team once the map is finished (Figure 6). The VLUP files are organized in the district office into separate GIS layers of land use areas (polygons), roads and other linear elements (lines) and places of interest (points). As the work process in the districts with GIS is not optimal, the geospatial data of the VLUPs (VLUP maps) is currently problematic and it is not clear what type of data each district team uses in the background of the map-making. In the final map layers, the land use types are overlapping, borders are inaccurate and sometimes areas are misplaced. There is a need to support and raise the quality level of the VLUP process from the perspective of the GIS working.

Figure 6 Example of a village land use map from Mavanga village with designated forest planation areas



Overall, the level of skills in managing GIS and digital special data is low and districts are lacking baseline data of the villages (satellite images, basic maps) to prepare the maps. Thus the VLUP process (Figure 4) does not use full potential of the geospatial resources and the quality of the VLUP maps does not fulfil general GIS data quality requirements (information consistency, spatial accuracy, data storage structure, standardization of map visualization etc).

The current drawbacks in the VLUP processes are:

- ➔ District PLUM teams have low level of GIS skills and knowledge of geospatial data management, visualization and map-making
- ➔ Spatial data used in village base map and existing land use and VLUP map production is outdated and inaccurate
- ➔ Poor knowledge of and access to spatial data sources (open access and commercial data sources)
- ➔ Low awareness of village population on VLUP and VLUP process which hinders participation and leads to persisting land and boundary disputes
- ➔ Village sketch mapping process is not done in cartographic scale, which produces arbitrary/redundant/inoperative sketch map of the current land use activities in the village
- ➔ Dependence on tedious field tracking campaigns due to lack of baseline geospatial data
- ➔ Undocumented individual land holdings in the village and potentially inadequate and /partial procedures to document and recognize private holdings in VLUP process

➔ Inaccurate and unstandardized map products as a results of the VLUP

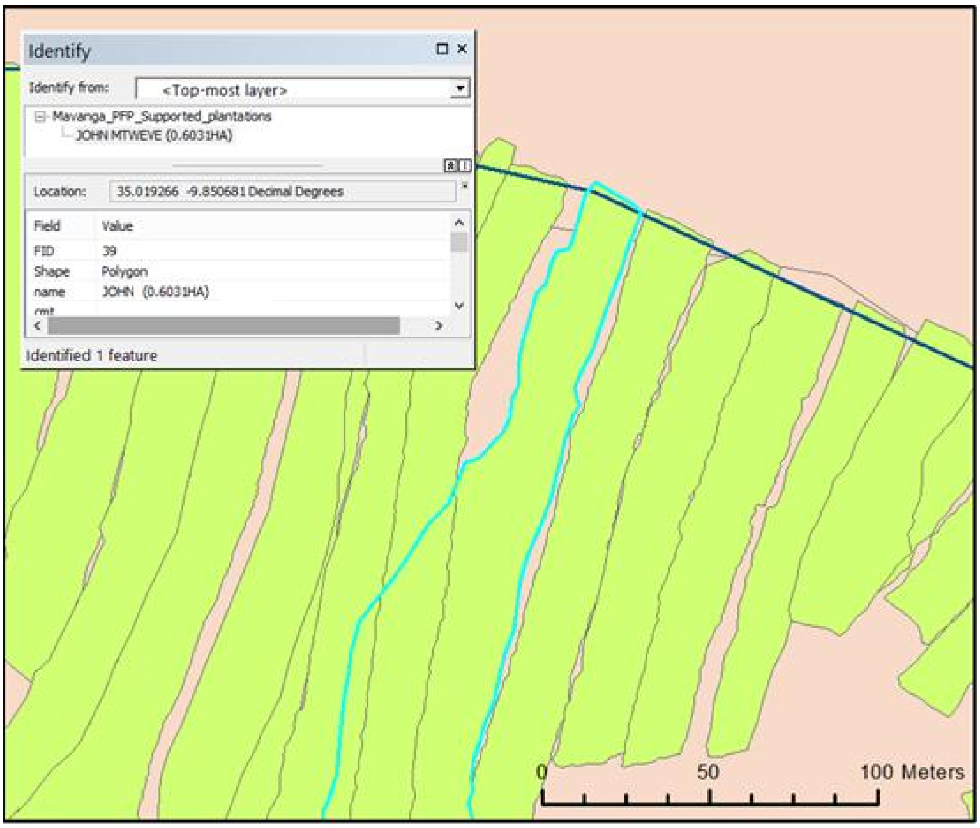
3.3 Plantation establishment and mapping of the private woodlots

After an area has been allocated for forestry, the TGA decides which area is planted during one planting season and divides the area between the TGA members (i.e. individual plantation owners). After this, the forest extension officer maps the designated plots together with the plantation owner using measurement stick and tracks the boundaries of the plots with GPS. Tracking is based on measuring the movement of the device as a sequence of points either along a time or distance gradient. The officers are using a distance gradient of 10 m.

After the tree planting, the process is repeated to map the actual boundary of the individually owned plantation plots. The mapping data (waypoints/track logs) is saved in the GPS and handed over to PFP office for editing. Editing includes cleaning topology errors, making sure each plot is a coherent polygon (area object with unique ID) and entering relevant attributes to the data. Currently there are no written instructions for the mapping work, and therefore the practices seem to vary between the extension officers.

All the areas, which were planted during the programme's first planting season 2014-2015 have been mapped with GPS, but most of the collected data still needs editing in GIS before it can be further utilized for data processing and analysis (Figure 7). The GPS data initially includes the plantation boundaries and ownership information. This data are mainly vector format data of polygons (areas). Other attribute data (tree species, density, etc.) is stored in spreadsheets and it is not directly linked with the plantation GIS data. Later on a spatial join will be performed to link the attribute data with the plantation boundary polygons.

Figure 7 **Plantation boundaries mapped with GPS and imported to GIS. Next step is to correct the overlapping boundaries and other errors in the data. Example from Mavanga village.**



Currently only plantations under TGIS are mapped by PFP. The status of the plantations established under the Outgrower Support Program (OSP) is not clear. They have likely been mapped, but PFP does not possess the data. In future, also the existing and new plantations outside TGIS and OSP are planned to be mapped, but the method for this has not been decided. Within the project area, there are other actors planting trees and supporting tree planting with interest in mapping the existing plantation resources. The Forestry Development Trust (FDT) has piloted an approach for plantation baseline mapping using Rapid Eye imagery and image classification techniques. At the moment, FDT is not selecting and mapping areas to be planted under the programme. The areas are selected by the tree growers alone, and therefore, FDT does not have any spatial information on the plantations that are established with their support.

3.4 Landscape, environment and biodiversity issues

PFP made a background study of the village land use planning process and identification of biodiversity values in the villages (Kabbala 2014). On top of this very basic background study, the programme has not yet conducted more thorough analysis of the landscape, environment and biodiversity related matters and their relationship to the programme activities.

PFP team has identified specific needs related to possible influences of the plantation development to hydrology and agricultural production downstream of the forest plantation. The team is also aware of the risks of planting on edaphic grasslands unless proper pre-analysis of the sites are not made. PFP is in need of geospatial analyses, which would be able to identify biodiversity remnants and hotspots of the region, including the edaphic grasslands, riverine forest, miombo and other natural habitats of high conservation value. Additionally the project needs solutions to estimate possible environmental impacts of plantation development to hydrology, other land uses and livelihood and to the landscape at large. FDT has identified similar concerns in relation to landscape influences of the plantation development. There is also an ongoing ecosystem/landscape service mapping research by the Universities of Turku and Dar es Salaam in the region (www.utu.fi/tanzania).

The VLUP process provides some room for consideration of environmental and biodiversity issues, but currently these issues are not explicit due to low knowledge of environmental issues in the PLUM team. There are no environmental officers from the local government in the team, but there are natural resource officers and/or foresters from the local government involved. Their knowledge on the environmental issues relevant to PFP is insufficient. The PLUM team has decided to establish 60m buffer around the forest plantation sites setting aside natural forests. However, there are practical drawbacks since water catchment areas and water sources existing in the area are not shown in VLU maps due to lack of tools to identify and map them early enough. Furthermore, cultural sites and ritual areas are not taken into account. The districts are in the process of recruiting Environmental Management Officers and hopeful they will be part of the PLUM TEAM in the future. For the PLUM team to work with reliable data on environmental issues, it would be good to get spatially explicit biodiversity data that can be used in the base mapping during the VLUP process.

3.5 Monitoring and evaluation (M&E)

The PFP aims to establish a robust M&E system covering each result area as a management tool for the project. For this, a monitoring plan is being developed, describing the indicators and methods of monitoring. The monitoring plan together with well-defined data collection procedures will allow the programme to continuously monitor the impacts of the different activities.

Currently the monitoring relies on spreadsheets. For example, the plantation establishment (TGIS) process monitoring starts by collecting data on TGIS milestones from the field. This includes activities related to proper land clearing & preparation, planting/fertilizing/blanking, weeding, and establishment of fire lines. The fieldwork is conducted by the forest extension officers, after which they deliver the data to the PFP office. The data is stored in Excel format, and processed using the visualisation and analysis tools of Excel. Most of the data is currently maintained by the Int. Junior Expert and the Plantation Forestry Advisor.

The current data storage system of the PFP does not support efficient monitoring since the geospatial (plantations as GIS files) and tabular data (spreadsheets containing TGIS and other data) are stored separately. Geospatial data is in ArcGIS/QGIS software and the non-spatial data in Excel. The PFP team has already made a plan of their integration, but this needs to put into a suitable data management model, which supports updating of both spatial and non-spatial data.

Currently some key data on i) area and quality of the existing plantations in Southern Highlands, ii) annual rate of plantation establishment, and iii) area available for tree growing is not available. The absence of this data makes TGIS monitoring problematic, as it is not possible to determine whether and to what extent the incentive scheme is affecting the rate of plantation establishment and quality of the timber. As discussed earlier in chapter 3.3, FDT is currently engaged in establishing the areal baseline data. There is also an ongoing study (Ph.D. and M. Sc. thesis in the Univ. of Helsinki) on the history and quality of the existing plantations in the area, which will produce valuable background information to M&E.

3.6 Human resources and training

PFP has recruited staff for the management of data resources and related operations of the project. Currently the following PFP staff and experts have key responsibilities in the collection, management and use of geospatial information:

- **10 forest extension officers** in the plantation mapping with GPSs
- **Plantation Forestry Advisor** in the establishment and monitoring of plantations
- **Land Use Planning, GIS & IT Expert** in the management of geospatial data and programme GIS and land use planning support
- **International Junior Expert** in the monitoring and evaluation
- **VLUP expert** in the preparation and steering of the VLUP process (soon to be replaced by a Community Development Expert under the TGA Apex body with wider responsibilities)
- **Forest and Market Information System Manager** in the development and management of forest information system (recruitment in process)

The Int. Junior Expert and Plantation Forestry Advisor are working primarily with tabular data of the plantations attributes, woodlot owners, TGA's, IGA's and related documentations. The Land Use Planning, GIS & IT Expert is responsible for inputting geospatial data into a GIS and in the management and spatial analyses of the data sets. This includes gathering and processing the GPS data coming from the field, editing the data into suitable format in GIS, making maps for various purposes, and providing IT/GIS and other support to all programme result areas. VLUP expert has been responsible for the preparation of the VLUP processes in the villages and proving support to the district PLUM teams. Recently, the VLUP expert resigned from the work, and VLUP support is planned to be transferred to the Community Development Expert (recruitment in process). The programme is also in the process of recruiting a Forest and Market Information Manager for the Apex body, who will eventually be in charge of the development and management of the Forest Information System.

Due to the limited amount of geospatial expertise, adequate resources have to be allocated in training the programme and Apex body staff. Table 2 describes the geospatial training that has been provided within the PFP. Further training needs will be identified in the PFP training strategy that is currently being developed.

Table 2 By August 2015, there have been six geospatial training sessions organized at PFP in collaboration with the partners.

Training	Timing	Place	Participants	Trainer
QGIS Training for VLUP	October, 2014	Njombe	District land planners/surveyors of Makete, Njombe TC, Njombe DC and Ludewa	Service provider (Aidan Mhonda)
GPS training	November, 2014	Njombe	PFP Extension Officers	LUP, GIS and IT Expert
GIS training	August, 2014	Turku, Finland	LUP, GIS and IT Expert	HEI-GIS, University of Turku/UDSM
Participatory GIS data collection and analyses	October, 2014	Dar es Salaam	LUP, GIS and IT Expert	HEI-GIS, University of Turku/UDSM
Open Foris (Earth Collect)	March/April, 2015	Njombe	PFP Extension Officers, LUP, GIS and IT Expert, Other stakeholders in Njombe	FAO/University of Turku
Participatory GIS data collection and analyses	February 2015 and August 2015	Njombe	District land use planners	PFP/University of Turku

3.7 Collaboration, communication and marketing

The PFP maintains active communication with relevant stakeholders though meetings, emails, and telephone. So far, some of the PFP data (work plans, reports, etc.) has been shared with key partners, such as the FDT, on ad-hoc basis. There are no formal channels or protocols for external data sharing. The same applies for internal communication, i.e. the project staff exchanges information on the need basis using emails etc. There is no server in place to centrally store and share data. The programme has purchased a network-attached storage for information sharing within the office, but so fat it has not been efficiently used.

At the moment, the map communication of the programme has concerned the visualization of the VLUPs against the woodlots, making maps of the PFP villages (as points) and visualizing basic infrastructure around the TGIS areas. The role of map communication is crucial for the project performance, both internally and with respect to the counterparts and collaboration. So far, the programme only has a basic communication plan, which does not include geospatial communication with maps and visualisations of the activities and project performance. A new communication strategy is currently being drafted.

The key partners of the PFP and the type of collaboration are shown in Table 3.

Table 3 PFP has established collaboration with several partners in the region, including key beneficiaries of the programme, administration, private companies, NGO's and academia

Partner	Type of collaboration
Ministry of Natural Resources and Tourism (MNRT) and Tanzania Forest Service (TFS)	Implementing partner with supervisory role. The PFP continually delivers progress reports and relevant documentation to MNRT. Active dialog will be maintained throughout the programme.
The District Councils	Collaboration and support for VLUP process, training in GIS, support to VLUP from PFP experts
Tree Growers' Associations and their Apex body	Key beneficiaries. Continuous support and collaboration through the TGIS.
The Forest Development Trust (FDT)	FDT has similar objectives than the PFP – synergies can found throughout the result areas, including working modalities, data collection, etc. So far, the collaboration has concentrated on information sharing through meetings and workshops.
Forest owners, forestry companies and related SMEs	Key partners for the PFP throughout the plantation value chain. Spatial information needed on resources, logistics, and industries.
Wildlife Conservation Society (WCS)	Collaboration on biodiversity and environmental issues
WWF	Collaboration on biodiversity and environmental issues
University of Turku (UTU)	Collaboration in research and geospatial training- MOU signed in 2014 on the issues of collaboration. UTU has MFA/Academy of Finland funded research in the same region (2014-2018)
Sokoine University of Agriculture - Faculty of Forestry and Nature Conservation.	Collaboration on forestry, biodiversity, and other issues
Eastern Arc Mountains Endowment Fund	Collaboration on biodiversity and environmental issues

4. DEVELOPMENT OF FOREST INFORMATION SYSTEM FOR PFP

4.1 Introduction to Forest Information Systems and existing solutions

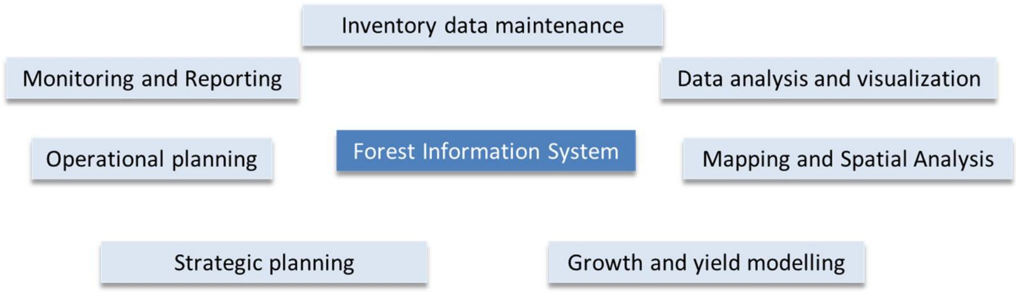
4.1.1 General functionalities of a FIS

Forest Information System (FIS) is a generic term for Information and Communication Technology (ICT) solutions used within the forest sector. The systems are used for storing, maintaining, and producing information on forest resources and for planning forest management activities. The design of a FIS can vary from a single user application with a small database (e.g. a spreadsheet with forest inventory data) to an enterprise-wide system with installations on many computers connected to a network with data servers. Annex 3 contains a list of various GIS/FIS software, which underlie many practical solutions.

The main functionalities/components of a FIS are described in Figure 8. However, depending on the varying needs for FIS, the systems can only include some of these components or have additional elements in it. For example, applications that are developed to store and disseminate data might only include modules that support these functions.

Applications that include modules for simulating forest growth and optimizing harvesting operations are developed to manage production forests, and are often referred as Forest Management Information Systems (FMIS). In commercial FMIS solutions (e.g. Microforest) the different modules are usually integrated and operated through a user interface. Commercial systems are developed and maintained by software developer companies.

Figure 8 Main components of a Forest Information System



The following describes the functions of the different components:

Inventory data maintenance. The backbone of a FIS is the forest inventory data collected from the forests. The quality of the input data in a FIS defines the usability of the system, as the outputs of the different components can only be as good as the source data. Therefore, the system needs to support reliable inventory data collection and maintenance procedures.

Data analysis and visualization. It is difficult to analyze and draw conclusions on the forest resources just by looking at the raw datasets. Therefore, FIS needs to be able to transform the data into information, i.e. create tables (statistics) and charts (visual data analysis).

Mapping and spatial data analysis. One of the most efficient ways to visualize forestry data is to create maps. Therefore, a FIS usually includes a map viewer or a more advanced GIS tools. The GIS-database can be integrated in FIS or operated through a separate GIS-software.

Growth and yield modelling. Forest inventory work is time consuming and requires a lot of resources. Therefore, the existing field inventory data is generally updated by predicting forest growth and development with growth models. Predictions of forest development under different treatment options, based on forest growth and yield models, form the foundations for decision making in forest management planning.

Strategic planning. In large-scale commercial forestry, a FIS needs to be able to simulate several development paths for the forest compartments and select the optimal path using the user-defined goals and constraints. The optimization result can be considered as a general management plan for the area which describes the operational schedules for each compartment.

Operational planning. The general management plans produced through simulation and optimization routines can be further utilized when preparing operational management plans for the management area. For example, the general plan can be visualized as maps to analyse the feasibility of the planned operations (logistics etc.). Modules for operational planning often include tools for budgeting and can be linked to accounting systems.

Monitoring and reporting. FIS generally has a component for producing easily understandable reports on forest resources.

4.1.2 Examples of existing FIS solutions relevant for PFP

There are numerous FIS solutions in use around the world. The design and structure of the systems varies depending on the intended use of the system. The following presents few of examples of relevant systems used in Africa and, as for comparison, in Finland. Finland is one of the world's leading countries in applying Information and Communication Technologies across all levels of society and different economic sectors. Alongside the rapid overall development of ICT, forestry sector actors have actively developed and applied different ICT solutions to improve efficiency. The lessons learned in Finland can provide guidance to the FIS development both in PFP and Tanzania in general.

In some African countries, national forest databases have been established. However, the usage of these is limited to governmental organisations and there are no descriptions available about their design and status. In Tanzania, the Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism (MNRT) maintains a national forestry database system called NAFOBEDA (the National Forest and Beekeeping Database). The objective of NAFOBEDA is to provide a tool to the FBD and Local Governments (LG) for consolidating and harmonising data collection and reporting procedures to monitor the status of forests in Tanzania over time. NAFOBEDA was not designed for programme or activity monitoring, but more for national and district level forest and forest management monitoring.

At the moment it is not clear if and how NAFOBEDA is used. The lack of data and system maintenance has reduced the usability of the system, and some sources indicate that system will be abandoned while a new system is being developed under the recently established National Carbon Monitoring Centre (NCMC). NCMC aims to collate all the forest and carbon data and make them available in the proper format for the national communication and GHGs reporting. One of the core tasks of the NCMC is the development and updating of the national baseline database using NAFORMA data. After its formal establishment, the NCMC legal mandate allows service providers to supply and update data through formal contracts. The Sokoine University of Agriculture has been appointed to be the host institution for the NCMC.

The most active users of FIS solutions in Africa are medium-sized forestry companies. In Africa, the leading FIS software in plantation forestry is called Microforest, which is an integrated forest management system developed in South Africa by Syndicate Database Solutions Ltd. Microforest is a commercial application with a monthly subscription fee. It has a large user base in South Africa, with users also in Swaziland, Zimbabwe, Tanzania, Mozambique, Uganda, Sierra Leone and Ghana. In Tanzania, it is used by Green Resources, Kilombero Valley Teak Company (KVTC), and the New Forests Company.

Microforest is a conventional web-based FIS application to support decision-making and to improve the efficiency of the wood supply. It has a modular structure, and the developer company customizes the application for each client. The company maintains the system from SA, and has a strong control over the usage of it. For example, access to the application is denied if the client is unable to pay the monthly fee. All modifications to Microforest are made by the developer.

There are few conventional FIS solutions available on the market that are similar to Microforest. These are all commercial systems with similar functionalities. Box 1 presents the functionalities of Microforest and a corresponding commercial FIS solution, IPTIM.

Box 1 Examples of commercial FIS solutions

Microforest

Microforest is an integrated forest and natural resource management system. It encompasses the entire life cycle of forestry operations and includes modules for managing inventories, modelling growth, harvest scheduling, planning operations and logistics. The main modules are:

Plantation Manager (PM) is a GIS based plantation management system. The foundation of PM is a comprehensive forest inventory database, including the plantation boundaries and enumeration data. Within PM, separate, customised modules are available for Plantations, Open/Natural Areas, and Infrastructure. The Operations module manages all activities related to any of these land uses.

Harvest Scheduling System (HSS) is a dynamic forestry modelling system used for strategic and tactical management planning. A simulation engine is used to model the events and activities that occur in commercial plantations. The user-interface allows the user to begin with simple simulations of the plantation management process and gradually refine the model as the understanding of the process and data improves. The system produces reports that enable analysis of the results at different levels or a consolidated view of the output from multiple scenarios.

Business Suite (BS) includes functionalities for monitoring (production, stock control, sales, and costs), budgeting, logistics, and valuation. It interfaces with accounting systems through a generic integration module.

(http://www.syndicate.co.za/files/microforest.html)

IPTIM

Iptim is a web-based integrated plantation management system with tools for data management and visualization, modelling, planning, and reporting. Iptim's modular suite of tools integrates data from all existing sources, granting the user a complete control of existing data.

Iptim's modelling tools enable the user to calibrate existing growth models or taper equations simply to better suit the existing data. With Iptim one can also model different management regimes, costs and timber prices in detail and modify the silvicultural and harvest operations to match the user's needs.

Iptim allows the user to create plans and predict outcomes of them. In the end, the system provides support for optimizing business strategies, refine existing operations and procedures and design the most effective use of the plantations.

The service is web-based, i.e. the simulations and other calculations are performed in the cloud. The system includes a map viewer for visualization and a QGIS plugin for additional GIS tools. The usage of the system is relatively easy through a simple user-interface. Iptim is developed and maintained by Simosol, Finland. The first version of Iptim was released in 2014.

(http://www.iptim.com/)

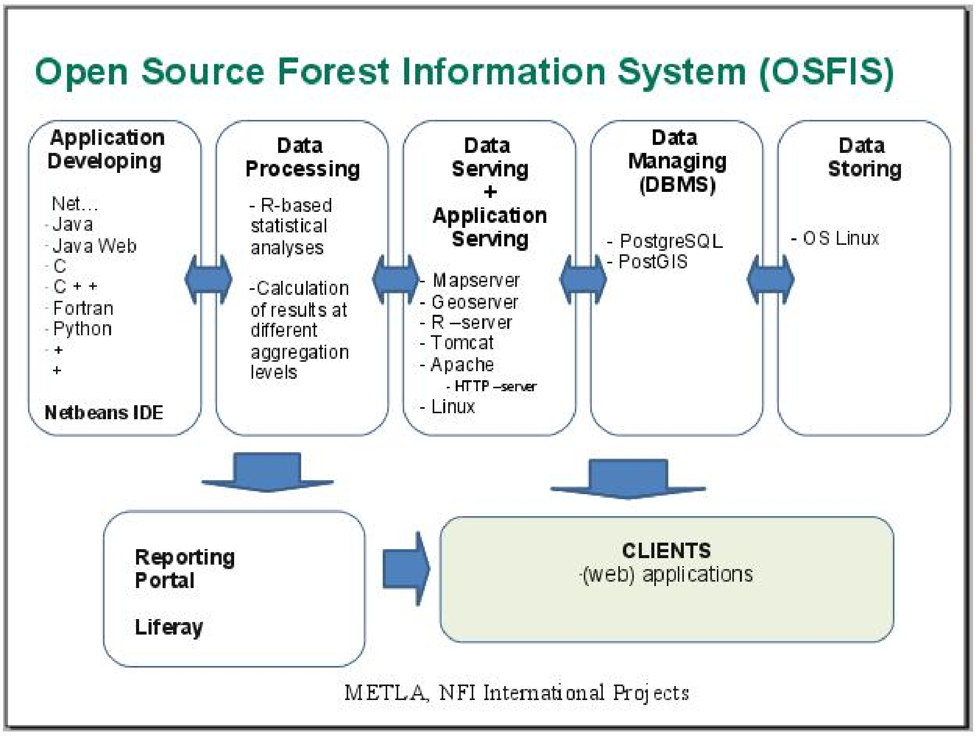
Currently there are no freely available Open Source (OS) based FIS solutions, that would include all functionalities of commercial systems. Therefore, OS solutions usually consist of modules that are built on different freely available applications. For example, the basic data is often stored in spreadsheets and/or a relational database and data processing and analysis conducted in a separate software (e.g. spatial analysis in QGIS). The different systems can be linked though database management systems (DBMS) and the data shared e.g. through a web-map service.

The Finnish Forest Research Institute (Metla) has developed OS based FIS structure that is designed to support National Forest Inventories (Box 2). A similar solution could be developed for the private sector, with extended functionalities for specific needs of the plantation owners.

Box 2 Open Source Forest Information Systems

Open Source Forest Information System by Metla

The Finnish Forest Research Institute (Metla) has recently provided support to National Forest Inventories in Nepal, Viet Nam, and Kenya. Within these projects, Metla has developed a design for an Open Source based FIS solution with the structure described below. The design includes modules for data management, processing, and sharing. The modules can be built on different OS applications.



In Finland, to understand the current situation with FIS solutions, one has to know some key facts about Finnish forestry. Firstly, most of the Finnish forests are privately owned. General information of the forest resources is collected through the National Forest Inventory (NFI), which is carried out continually in five-year cycles. The data produced in NFIs is public and available to all actors in the forestry sector at the cost of the data provision, as the government funds the data collection. NFI data is provided up to municipality level, and it is not intended to be used for operational forest management planning at property level. Property-level inventories and forest management planning are carried out by Forest Management Associations and other service providers.

By law, the property-level forest information is comparable to banking secrecy and is to be treated confidentially. The forest information on private properties is available only to state officials and the property owner, unless the owner authorizes officials to provide the information for other indicated purposes. The legislation on the sharing of data has considerably affected the ICT solutions used in forest management. There is no common database/GIS system and most actors have created systems for their own purposes and for the management of data to which they have access. These are generally conventional FIS solutions developed by software development companies.

Recently there have been significant developments in data collection and sharing protocols in Finland, which have enabled the development of web-based information management systems that serve the needs of different actors. Paikkatietoikkuna, the portal of the Finnish National Spatial Data Infrastructure is one good example of such development (paikkatietoikkuna.fi). One of the critical steps towards more integrated FIS solutions was the establishment of Forest Information Standards. The standards include detailed descriptions of how and what kind of information is collected from the forests (inventory data, operations, market data, etc.). As most actors have adopted the standards, the data in the various systems is nowadays widely in a standard format, and therefore their systems are able to communicate with each other. The new solutions have reduced the inefficiencies related to the use of various systems and data management procedures. In addition, the scope and extent of ICT solutions applied in forestry and forest industries have become wider than before.

Also in Finland, the importance of communication between forestry actors (forest companies, governmental organisations and forest owners) and the general public has become an emerging requirement, and new solutions have been introduced to respond to the needs in this area. Two examples of new solutions, Metsään.fi and Puumarkkinat.fi, are presented in Box 3. These are both web-portals that respond to the varying needs of the different actors, including forest owners, forest management associations, and timber buyers.

Box 3 Finnish solutions for forest and market information management

Metsään.fi

Metsään.fi (in English the meaning of “Metsään” is “To Forest”) is a portal which offers the latest information to forest owners on their properties. As soon as they log in, users can see the details of their forests (inventory data) and recommendations on what should be done in their forests right now. Information is displayed for each forest compartment, broken down by soil type, tree type and natural occurrence, and possible logging or forestry actions are suggested, including income and cost estimates. Maps and aerial photographs clearly show where properties are located and what they look like. Users log in securely using their online banking codes.

Forestry businesses, forest management associations and timber buyers can also be found in the portal. Forest owners can check which service providers are available in the area surrounding the forest property, and, if necessary, authorise chosen partners to view their data or transfer them to their own systems. This makes it easy to get in touch with professionals regarding forestry and logging work. Service providers may also contact forest owners on their own initiative.

The portal saves service providers the cost and effort of visiting sites to obtain the latest data on which to base plans. It also contains up-to-date contact details for forest owners. The aerial photographs and maps are important tools for professionals, and for small businesses, Metsään.fi may replace the need to have their own GIS or CRM system entirely.

The portal draws information from a national forest resource database, which is continuously updated with data obtained by laser scanning, aerial photography, sample plot measurements and site visits. This sort of data collection is a statutory task of the Finnish Forest Centre (governmental organisation). Between surveys, information is maintained based on notifications received by the Forest Centre from forest owners and forestry organisations.

The portal is developed and maintained by the Finnish Forest Centre and funded by the Finnish Ministry of Agriculture and Forestry.

(http://www.metsaan.fi/)

Puumarkkinat.fi

Puumarkkinat.fi (in English the meaning of “Puumarkkinat” is “Timber Markets”) is a nation-wide web-portal aiming at increasing the efficiency and transparency of timber markets in Finland. It is an electronic bulletin board, where the Forest Management Associations post information on the standing timber that is currently for sale within their management area (after receiving an authorization from the forest owner). The details of the stand (timber volume by species and assortment) can be viewed by all registered timber buyers. The buyers can follow the available timber volumes in real time, search available resources near to them and make offers on the most suitable resources.

The forest owner can see his information in the portal, view local price statistics and receive bids on the timber that he/she has is for sale. In future, the forest owner can also post information to the portal directly, without contacting the Forest Management Association.

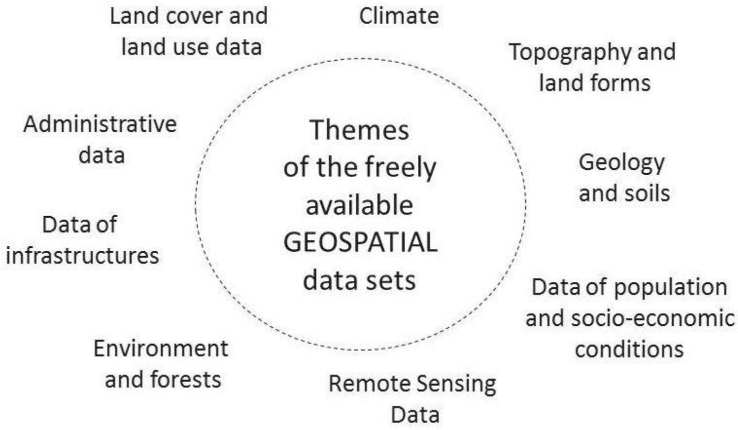
A significant part of the timber sales in Finland are nowadays conducted through the portal. Puumarkkinat.fi is developed and maintained by a private company called Silvadata Oy, and funded by the the Central Union of Agricultural Producers and Forest Owners (MTK).

4.2 Data and system requirements of PFP

4.2.1 Available geospatial datasets and their feasibility for PFP

There are substantial amount of freely available geospatial data from the programme area (see Figure 1) concerning wide range of themes (Figure 9). Most of these data sources are suitable for regional/district level operations of PFP and they also provide valuable material for various pre-assessments, such as selection of target villages, suitability analysis of sites for plantations (topography, accessibility) and evaluation of the environmental effects.

Figure 9 Reviewed geospatial data sets were related to wide range of themes.



However, there are substantial gaps in the availability of free data for local scale programme activities and therefore PFP is faced with a practical need to purchase or produce spatial information themselves or in collaboration with the other actors in the area. We have made a feasibility evaluation of the types of free data in the Annex 4, and summarized the data situation, gaps and needs below.

Data of infrastructures

The programme has needs for reliable geospatial information of the existing infrastructures, such as roads and locations of key forestry actors (industries, market places) in the region. This information plays an important role in the decision-making processes of plantation establishment and their accessibility and cost estimates in the phases of the monitoring, harvesting and marketing.

Currently, there are substantial gaps and quality problems in the existing spatial data of roads, buildings and services in the Southern Highlands. Data of the building does not exist in digital form and data about the services is also sporadic. Furthermore, the official road network of Tanzania does not exist at the level of accuracy needed for road network mapping, navigation and accessibility estimates. While Google Open Street Map (OSM, https://www.openstreetmap.org) provides the most complete coverage of road network, there are severe inconsistences in the data: not all roads are mapped, the attributes of the data are not consistent, existing roads do not establish a uniform road network (road junctions are incorrect and misplaced) and the data is constantly changing. This is obvious as the OSM is a freely developing words map based on the input of the users. The road data of the African Development Bank Group is another national road data, but it contains only the main highways and is not regionally accurate enough for the PFP needs.

As a summary, the existing road data may be used for regional map visualizations, but not for any distance, accessibility and cost calculations. Thus PFP should find a solution to map the existing road network either from the high-resolution satellite images (via publicly available internet image resources) or/and through mapping the roads with GPSs installed in moving vehicles). In both cases, there should be a discussion of the required accuracy for the data collection as well as decision upon what information of the roads is stored into the GIS.

The most fundamental requirement for road data in a GIS is that all road sections are physically linked to each other as a coherent network of lines and intersections, and that all the roads have indication of their quality for vehicles, speed and access (such as surface material, average width, possible obstacles on the road etc). It is possible to use the existing OSM data are a starting point and supplement the data, in case the existing data can be evaluated first against the images or already collected road data by the project.

As the information of the existing locations of forestry sector actors and services (supply, markets) is missing, PFP needs to consider how to collect this information and attach it into the road network database. Once the road segments and their attributes, intersections, impediments (such as bridges, erosion sites etc,) and services are all in the same network database, it is possible to do cost-distance, location-allocation and travelling salesman –type of calculations, which would help in optimizing establishment of plantations sites and especially their harvesting and market operations.

Administrative data

The latest administrative areas of Tanzania (regions, districts, wards) are openly accessible as shapefiles (shp) from the National Bureau of Statistics (NBS) website. The areas are published as part of the latest census 2012. The site also provides administrative areas from the previous census (2002). From 2002, the boundaries of the census enumeration areas are also available.

The boundaries of the administrative units between years 2002 and 2012 differ from each other. Some of the changes are true, but it seems that the ward boundaries are digitized in 2012 with no relation to previous borders in 2002. This makes it difficult to compare any thematic changes based on administrative areas.

In addition, government offers boundary files of the villages, which are used in the VLUP as a reference. However, the perceived boundaries by the villagers often do not coincide with these official boundaries and thus the PLUM team have to map the boundaries with the village representatives using GPSs. In this process, it is difficult to state if the perception of the boundaries with the neighboring villages is the same or not. Disputes in the administrative boundaries are often reality.

VLUP process is suffering from the lack of reliable administrative data concerning the village boundaries and as the VLUPs are usually not done simultaneously in the neighboring villages, there is a risk that the boundaries are not commonly accepted/acknowledged.

Data of population and socio-economic conditions

Tanzanian latest two population censuses were carried out in 2002 and 2012 and these data is available at ward level summary statistics of males, females and household sizes. Population estimates of Tanzania for 2010 and 2015 can also be found in raster format (population grids), which are based on combining the census calculations with physical locations of the settlements. While the first one allows thematic maps to be made out of population differences between the administrative areas, the latter allows more geographically distinct analysis of pollution distribution. Previous censuses were conducted in 1988, 1978 and 1967, but these are not available in digital spatial form.

Socio-economic data can be derived from Demographic health surveys (DHS) and Agriculture Sample Census (ASC) and Tanzania HIV/AIDS and Malaria Indicator Survey (THMIS). Latest DHS was done in 2009/2010, ASC in 2007/2008 and THMIS in 2011/2012 in Tanzania. All of the censuses hold valuable socio-economic information. This data is important to study the socio-economic impacts of tree planting activities. However the online free access data is only available at regional scale and it's too scarce for any detailed use. According to the questionnaire sheets ward level spatial information should be possible to trace for each response, but this data should be separately acquired.

Both PFP and FDT have conducted household surveys in the region of the Southern Highlands. It would be useful for both programmes not only to share the key findings but also aim to establish some shared HHS indicators to measure the livelihood and poverty reduction impacts of the programmes to local communities. It is also advisable to share information of the target villages, their location and background socio-economic conditions.

Much of the detailed socio-economic information needs to be collected as part of the PFP programme. When doing so, it would be recommended to select the sample sizes (HH numbers/village) proportioned to the population sizes of the wards and villages so that the data is geographically representative when surveys pile up or when they are repeated.

Topography and land forms

Topographic information will be important for plantation establishment and management. Good quality information of the land forms such as steepness of the terrain can help PFP to estimate the growth condition, water flows and erosion risks of the plantation areas and to estimate the accessibility of the sites. Topographic information can also help PFP and the government in road construction and planning.

As the latest Tanzanian topographic map series are from the 1960’s, it is advisable to review if other digital elevation models (DEMs) over the area would support the mapping and modelling of land forms and topographic conditions. There are two global moderate resolution digital elevation model (DEM) datasets available; ASTER GEODEM 2 and SRTM. These dataset are at the spatial resolution of 30x30 m and their vertical resolution allows basic analysis of topographic differences within and around the plantation areas (depending on how small are the allocated plantation areas). For sure, these data sets are sufficient for regional scale land form mapping and analysis.

Since the SRTM DEM has better vertical resolution than Aster GEODEM, it is suggested for PFP to produce the following background models for land form mapping and modelling:

1. *Contour model (calculated elevation contours) for visual display on top of various maps of the project, including VLUP resource maps*
2. *Slope model, which indicated the maximum inclination of the terrain (in degrees)*
3. *Aspect model, which indicates the compass direction of the slope*
4. *Water catchment model, which can give an indication if the size of the water catchments*
5. *Flow accumulation model, which can give an indication of potential location of water flows and their concentrations (as rivers)*

Climate, geology and soils

Tanzanian meteorological institute (TMI) has several weather stations over the area of the Southern Highlands, but the data records are not digitally stored or their locations are openly available. However, the WorldClim database contains several bioclimatic parameters at the scale of 1x1km, which can be used to obtain broad overview of the temperature and rainfall patterns of the PFP operative area. The monthly records of the Tanzanian weather stations records from the 1950 to 2000s have been used in the background of these interpolated data sets. Large scale climatic patterns have been integrated into the interpolation, but since the weather stations are not uniformly distributed over Tanzania, this creates uncertainly into the data. Unfortunately, there is no data available regarding micro-climatic site conditions, nor access to original records of the TMI. Availability of geological data and particularly soil data is poor. The Harmonized World Soil Database and Soil Grid of Africa offer 250x250 m general level information of the soil classes and soil properties, but these will not allow any local level interpretation.

PFP made a report of existing rainfall patterns by Anderson in 2014. The rainfall estimates are less detailed in this report than what WorldClim can offer. It is suggested that PFP revises their background analysis of rainfall patterns with the help of WorldClim variables, which can be used to map approximate areas of sufficient rainfall for plantation development. As the approximation was already done in a previous consultancy, it is suggested that GIS staff of PFP goes through the site estimates and double-checks the consistency.

In case PFP needs more accurate soil information from the plantation sites, it should be done in the field and decided at which detail and which methods plantation woodlot and their soils properties could be estimated and recorded. Soil data was extensively collected as part of NAFORMA. These records may provide important reference information of the soils properties for PFP, especially if some rapid field based techniques could be linked with dominating soils types and their properties measured elsewhere.

Environment and forests

The data concerning the status of the environment is sparsely available in the Internet. The Global Forest Change dataset (Hansen et al.) and World Database of Protected Areas (WDPA) as the most important openly available environmental datasets.

Global Forest Change dataset, which provides GIS data of the forest gain and loss estimates at the spatial scale of 30x30 m within a time span of 2000-2012, is a good baseline data to compare with the possible land cover mapping exercises and also concerning the target areas. It is important to accept, however, that the data set may not be valid at very local scales and the landscape of the southern highland is particularly challenging as the plantation development has been so fragmented and planted areas are relatively small. Thus, the accuracy of the data sets needs to be considered carefully.

Different projects and actors most likely hold various environmental data, which are important for PFP if any environmental/landscape/biodiversity information is needed. It is likely, however, that this information is not available over the whole region. It is suggested that PFP seek to establish good working linkages with environmental organizations such as WWF, WCS and IUCN to obtain their information for collaboration.

The World Database of Protected areas (WDPA) from the IUCN contain information of various types of protected areas in Tanzania, but unfortunately not all local protected areas are in this database and the delineations of the borders of the protected areas are not always accurate. For example, village level forest reserves and sacred sites are not perfectly mapped.

It is possible for PFP as part of the village land use planning process to obtain valuable information concerning locally relevant environmental information. Most of the natural values in the villages relate to forested environments and riverine sites as well as natural grassland of high biodiversity value. Some of these information may also be possible to obtain from the local administration offices.

Land cover and land use data

It is relatively essential for PFP to be able to estimate the current status of land cover and land uses in relation to plantation planning and development. This information is needed both at the strategical regional (where to plant and why) and at the local scales in order to compare already existing plantations and other land uses in relation to PFP supported plantation development. PFP is also likely to need regional scale land cover data for larger environmental/landscape assessment in order to identify potential areas for plantation development and to avoid areas where land use conflicts may occur or where other ecosystem than forest plantation values lie.

PFP has a need *to map existing land cover patterns* for the several purposes: Firstly, the project needs a baseline of the existing forest plantations in order to estimate where, when and how much forest harvesting may take place in the region. Secondly, the project needs to estimate how forest plantations are currently established and managed in relation to other land uses, such as agricultural produce and protection of natural forests, edaphic grasslands and riverine forest and scrublands. Thirdly, land cover information are needed for the VLUP, where one important step of the process is to map existing land uses in the villages. PFP needs for land cover and land use data vary in spatial scale and at strategical level PFP needs regional estimates of the forest stock and distribution. At local scale the needs are more explicit as PFP needs to assist TGA in their proper and cost efficient management of forest plantations.

There are several data sources, which offer national and regional scale estimates of the land cover and land use distributions in Tanzania. These data sets employ different land cover classification systems and are also variable in their accuracy (spatial, temporal). The most updated national scale land cover maps were done as part of the National Forest Resources Monitoring and Assessment project (NAFORMA) in 2009. However, this data is very course scaled spatially and it contains only 17 land cover classes nationally. Global land cover maps (Africover, GlobCover) are more detailed in their classification hierarchy and also in the delineations of the patches, but do not offer suitable land cover information to match the needs of land and forest resource mapping and planning at the scale of the villages and TGA's activities Additionally, the Africover database is also outdated (1997), but could be used to do some type of regional change estimates of land cover, when combined with more up-to-date sources.

Considering PFP needs, none of the existing land cover data sets are suitable for local scale mapping and analysis of land and plantation forest patterns. None of the existing data sets are also suitable for mapping forest plantations at regional scale since plantations have not been the focus of the generalized land cover mappings. As a consequence there exists no information of the distribution of the existing plantations, or explicit spatial knowledge of other land uses and valuable biotopes/habitats. PFP needs to produce this information as part of the projects activities, preferably in collaboration with other actors, who also have expertise in forest plantation mapping, mapping of land cover and land uses and specific biotopes/habitats of protection value. The most feasible methods to do the data collection is to use remote sensing imagery combined with supplementary information collected in the field or from existing data repositories of the other institutions.

There are several feasible options for PFP to establish regional and local scale maps and estimates of land cover and land use information, such as:

1. To *use freely available remote sensing data* (Landsat OLI, Sentinel2) to map or to make reasonably accurate spatial (samples) estimates of the land cover patterns and plantation areas within the whole region and within districts and wards. These data sets can be used through simple visual interpretation, but can also be automatically classified and analysed. Currently, Sentinel2 data is not yet available, but will be within some months to come. There are several Landsat OLI images of the region already available. Most of the images of the dry season are also cloud free. In case of OLI image, image fusions between the panchromatic 15 m and multispectral 30 m images could work fine of visual interpretation work.

2. *Invest in purchasing medium scale satellite imagery* together with the other actors over the Southern Highlands region and use automated and visual image interpretation method for the mapping of the land cover and existing plantation patterns. Forestry Development Trust has been asking PFP's interest on sharing the costs puchasing licenses of Rapid Eye imagery to be used for mapping of the existing plantations. Such a baseline would be important for both programmes. Before deciding upon the data purchase, PFP should: a) estimate the total costs of the imagery and conditions of the user license (how many users are allowed, can data be shared to collaborative partners (districts, NGOs, academia etc), b) estimate the costs of the mapping of the existing plantations in case the mapping contains wall-to-wall (full cover of SH area) mapping of the plantations patches and their age estimates. In case PFP invests money in new imagery, it would be recommended to promote the use of the imagery in multiple purposes of the project (as listed

above in this chapter). If the mapping of the plantations is outsourced to expert company, it is advisable to check if the existing algorithms of FAO and NAFORMA would work for the plantation mapping.

3. Use *available Google or Bing map images* (which use for example Digital Globe satellite image products) as a background in a GIS software (QGIS) and visually interpret and digitize main land cover and forest plantation areas from the target villages (mapping existing plantations in each target village). This option should also be tested for the overall VLUP support, where there is a need to map existing resource base and communicate with the village residents through maps and images. The main disadvantages of the internet-map approaches is that some areas will always be cloud covered or missing most accurate data and thus there might be risks of not being able to repeat the mapping process with equal confidence in all the sites selected for VLUP and for plantation establishment. Option number 1 (Landsat OLI fusion image) or 2 (Rapid Eye) might offer a feasible options to VLUP land use mapping

Remote sensing data

Since the geospatial data gaps in the Southern Highland region are relatively severe, PFP needs to consider options for either using freely available satellite imagery or purchasing images for the generation of critical information for the management of the programme activities (as suggested in land cover and land use data). The usefulness of satellite imagery is a combination of several factors: What is the intention of the mapping, what type of phenomena is being mapped, how accurately the mapping should be spatially (full geographical cover or sampling) and how often the mappings should be repeated over time. There are several PFP result areas, which depend either fully or partially on the use of good quality remotely sensed imagery. To sum up, these are:

→ having a spatial estimate and/or map of the existing forest plantations so that plantation management is efficient in relation to PFP introduced woodlots and already existing plantations of the TGA members and other actors in the region. PFP needs to decide if the mapping needs to be taken at the scale of individual woodlots and their ages over the whole operation area (as suggested by FDT) or if it is sufficient to know the quantity and quality of the plantations as estimates only (sampling).

→ Monitoring changes and development of plantation resource base over time regionally and locally. PFP needs to decide if the monitoring requires wall-to-wall information over the whole operation area or if it is sufficient to know the quantity and quality of the plantations as estimates only (sampling). In case the project needs repeated monitoring of the individual plantations areas, aerial images from drones or from light aircrafts may work out. However, introducing new imagery into monitoring process is likely to require substantial human resources for the processing and interpretation of the imagery. Thus other monitoring solution may be better.

→ Improving the Village Land Use Planning process especially in the mapping of the existing land resources and generation of the baseline map information (see chapter for VLUP for more suggestions)

→ Any spatially explicit assessment of the status of the environmental or potential biodiversity in the landscape is based on good quality land cover/biotope/habitat information, which cannot be obtained from existing data resources, but need to be either mapped or sampled from the remotely sensed images either by PFP staff (if skills exists) or outsourced to collaborative partners.

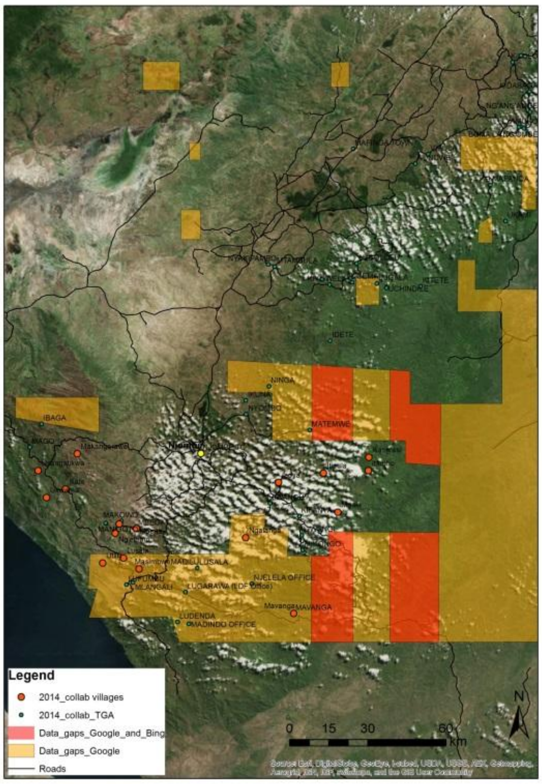
Currently, the full availability of free online satellite imagery is mainly restricted to medium scale imagery, such as Landsat OLI images of the USGS (spatial resolution of 30x30m, 15x15 m pancromatic). As European Space Agency (ESA) launched a new SENTINEL-2 satellite in March 2015, it will soon provide very similar remote sensing material free of charge for land cover and land use mapping globally. SENTINEL-2, which has improved spatial resolution compared to Landsat OLI, will offer a tempting solution for near-future land cover mapping at the spatial scale of 10x10m.

Commercial companies provide wider range of medium and high-resolution images for the clients, but their costs easily increase once the target area is large and the image market price varies dependent on how many users of the data there are. On top, the availability of the good quality images over large areas at least approximately at the same time of the year is sporadic. This is due to vulnerability of optical satellite to prevailing weather conditions (cloudiness, haze). Rapid Eye is a relatively new commercial satellite system, which has improved yet still manageable spatial resolution for regional land resource mapping. High resolution products, which easily reach the spatial accuracy of under one meter, are usually too detailed and inefficient (too large data sets, unreliable coverage) for regional mapping, but very useful for any detailed mapping of the land features (eg. roads, bridges, houses, detailed woodlots). One of the most accurate commercial satellite systems is World View of the company Digital Globe. These images and their predecessors of Geo-Eye and Ikonos are familiar to the users of the internet maps, such as Google Maps.

High resolution satellite image data is provided globally by Google and Bing via their respective Internet map services for visual inspection. They offer online navigation of the images and also allow image visual interpretation in GIS software. ESRI (ArcMap) is collaborating with Bing and provides access to the internet map service through ArcMap Online Maps service. QGIS is collaborating with Google maps and allows image access via OpenStreet plug-in. The online uses either in the Internet or In GIS software requires Internet access. The Google images can also be downloaded over restricted areas with reasonable quality on your own computer. However, the full resolution and capacity of the images can only be accessed through the commercial purchase of the images.

One of the key challenges of using online web map options for image analysis is the need for constant Internet access, risk of working within the areas where there is lack of high-resolution image or that the existing coverage is hindered. Additionally it may be that the images are already several years old and there is lack of necessary metadata details of the images. Most important metadata is the date of image capture and this can be found from both service providers (Google and Bing). Bing maps have a separate map service for image date description that is in http://mvexel.dev.openstreetmap.org/bing/. Here a few month window is given to spatially most accurate images. The sensor and spatial resolution are not provided. Google image dates can be found from google earth or from google maps map editing interface. From map edit interface also data provider is named but the resolution and sensor is unknown. Most up to date images are generally provided by Google maps. In Southern Highlands area they are currently from 2012. Google also updates the images every now and then. The latest update concerned April 2015 images but Tanzania images were unfortunately not updated. Bing maps are usually bit older for the Southern Highland area (either 2009 or 2010) compared to Google Map images (see Figure 10 for Google and Bing high-resolution image coverage in relation to PFP villages in 2014).

Figure 10 Map of the current availability of high-resolution images in Google and Bing maps from the region of the Southern Highlands.



The rights for imagery through the online services are ambiguous, and should be considered. On the Google Map pages it says that “You can personally use an image from the application (for example on your website, on a blog or in a word document) as long as you preserve the copyrights and attributions including the Google logo attribution. However, you cannot sell these to others, provide them as part of a service, or use them in a commercial product such as a book or TV show without first getting rights clearance from Google.”

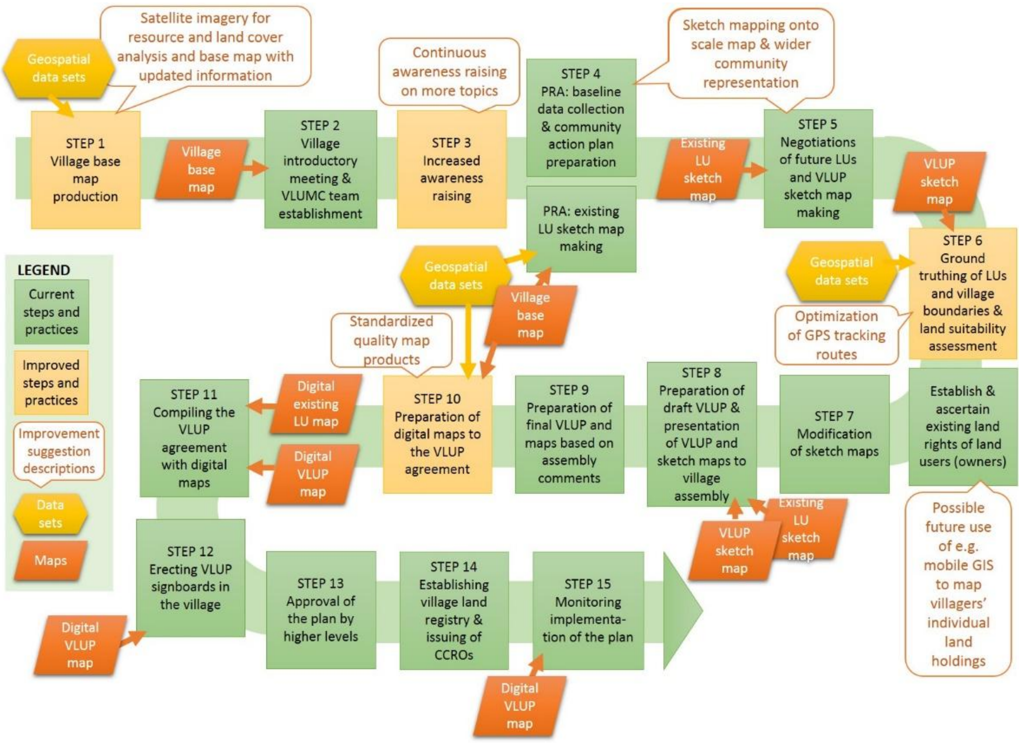
4.2.2 Village Land Use planning using spatial data and GIS

VLUP process is district PLUM team effort supported by PFP, where professional uses of geospatial data, GIS and practices of participation are fundamental. PFP can support and improve the quality of the process with its expertise in many concrete ways (Eilola et al. 2015; Fagerholm et al. 2012; Flintan 2012; Kyem 2002). Below we have complemented the shortcomings listed in chapter 3.2 with suggestions of action for PFP. Figure 11 outlines the steps in the VLUP process in which geospatial data and technologies as well as increased awareness raising can be employed to improve the process.

- **District PLUM teams have low level of GIS skills and knowledge of geospatial data management, visualization and map-making.** PFP should make a proper plan how to improve the skills levels of the district officers in their VLUP tasks related to use of spatial data and GIS. The training and support plays an important role also in the motivation of the PLUM team for VLUPs and has wider implication for geospatial capacity development of the administration in the Southern Highlands.
- **Spatial data used in making village base map and existing land use map production is outdated and inaccurate and there is poor knowledge and access of PLUM team to spatial data sources (open access and commercial sources).** PFP should use their financial resources to provide better data for the mapping exercises of the VLUP (base mapping, existing land use mapping) and train officers in the use of existing spatial data.

- **Low awareness of village population on VLUP and VLUP process hinders participation and leads to persisting land and boundary disputes.** PFP should promote awareness-raising of community on VLUP process, land rights, environmental conservation values and VLUP benefits (this creates enabling environment for participatory process, mitigation of conflicts and informed decision-making for VLUP (Hart et al. 2014; IFAD 2009). PFP should promote transparent village boundary verification process with neighbouring village representatives and possibility to show disputed village boundaries in the VLUP maps. If the boundary dispute continues to persist at the end of the VLUP process this allows the process to continue in the village outside the disputed area while resolution continues to be sought.
- **VLUP maps in different stages of the process are unstandardized and thus difficult to evaluate in terms of their information content, work redundancy, information quality, distortions and gaps.** PFP should strengthen the GIS operations of the VLUP by supporting village base map making before the VLUP intervention in the village happens, reducing and optimizing the amount of time needed to map existing land cover and land uses in the field by GPSs, supporting village sketch map making, which currently is completely detached from cartographic scale mapping and improving the overall visual quality of the VLUP maps, which are the final products attached to VLUP agreements (see Figure 11 below).

Figure 11 Multiple steps of VLUP process, where geospatial information, GPSs and GIS technologies are used. The village base map, existing land use map and the final VLUP map are all dependent on professional use and collection of information under the respect of community's right to participate and govern the process of local land use planning (Figure: Salla Eilola).



As the VLUP process is not governed by PFP, it is advisable to create an agreement with districts of the data sharing and GIS support in the VLUP process. PFP could offer their FIS as a reliable storage for the GIS data layers of the VLUP maps and also provide districts with storage of any other GIS data layers and map products, which are created along the VLUP process.

In the current VLUP process, the existing land resources are not thoroughly mapped and PFP could consider if their staff could also take part in the mapping of the existing land uses and plantations, for example. This would require remote sensing imagery in the background. For the future, the geospatial capacity development for the district PLUM teams should aim at skills levels such as satellite image interpretation and analyses, which will enable them to carry out more thorough village resource and land suitability assessments using geospatial data and technologies.

Before VLUP process improvement decisions can be fully made, it is recommended that PFP runs through a set of tests in selected villages to gain experience of which practices work best and discusses with the PLUM teams of their needs and wishes and their skills development. PFP is planning to do one test in October 2015 with the University of Turku and Iringa Living Lab in Nhungu village (Makete district) as part of the new VLUP process (Appendix 5).

4.2.3 Mapping the plantations and establishment of a plantation database

The plantation database (incl. geospatial and tabular/inventory data) will form the backbone of the FIS. This requires reliable and up-to-date data on location and area of the plantations, i.e. mapping of the plantation boundaries either in the field (GPS) or from satellite/aerial images. The current practice of PFP for mapping the plantations will provide the needed data for areas under the TGIS. However, as the objective of the FIS is not only to serve the needs of the PFP, it should also include information on all existing plantations in the region. It is expected that the baseline will be mapped or sampled at a coarser scale from satellite images (see section 4.2.1 for data alternatives in land cover and land use mapping) and the mapping of the new plantations is done in the field with GPS. To build a comprehensive database, the data collection procedures should be synchronized within the PFP (extension officers) and between the different actors (especially PFP and FDT). This includes mapping of the plantations and other spatial data collection procedures.

Besides the TGIS, PFP is also supporting the development of viable income-generating activities (IGAs), such as growing beans, avocado's and beekeeping. Data for these IGA projects are currently stored and processed as separate tables for each IGA type (beans, avocado's, etc.). As the lifespan of the IGA projects can be short, the projects are not mapped. The IGA projects are initiated by those individuals, who take part in the plantation activities. The link between the beneficiaries (farmers), plantations and IGA projects is a key for sound management and avoidance of data storage repetition.

It is recommendable for PFP to standardise and instruct even more carefully the current mapping procedure of the household/individually owned woodlots in the field and also establish good working procedure for the woodlot boundary and attribute data editing and management in a GIS software (QGIS) before the data is entered into FIS (Box 4).

Box 4 Suggested complementation of the existing woodlot mapping procedure for PFP

Woodlot mapping procedure with GPS in the field

Forest extension officers are key persons to measure and map the individual woodlots in the field inside the VLUP designated forest plantation areas. Their work is based on using Global Positioning System (GPS) together with the measurement sticks. The mapping sets the foundation for the most detailed level information of the PFP woodlots in the FIS.

The woodlot mapping instructions can be given out as an A4 2-sided laminated instruction sheet for the forest extension officers. The instruction should contain the following:

a) Step-by-step instruction for the tracking of the woodlot boundaries in the field using track log of the GPS (with distance interval of 2-3 m) in Arc 1960 UTM 36S coordinate system. After which the track log is wrapped and named with a unique ID and owner initials (or full name).
b) Marking each corner of the woodlot during the tracking procedure with waypoints (naming WPs using the same plot ID + running number). When marking the WPs, it is recommended to use the averaging option in GPS so as the reliability of a single x,y coordinate pair becomes better.

The idea of using both track log and WPs is that the track log gets easily distorted due to the movement of the person and inaccuracy of the consecutive measurements. WPs allow making the borders of the plot straight and simplifying the shape of the woodlot in GIS after the mapping.

The back side of the laminated A4 sheet should contain technical instruction of the GPS device and issues to check before the measurements are taken, including the coordinate system, track log settings, storage space etc.

In case the extension officers have paper, pen and cameras, they should also be instructed to make sketch maps of the plots and their placement in relation to each other and take photographs of some of the boundary measurement sites.

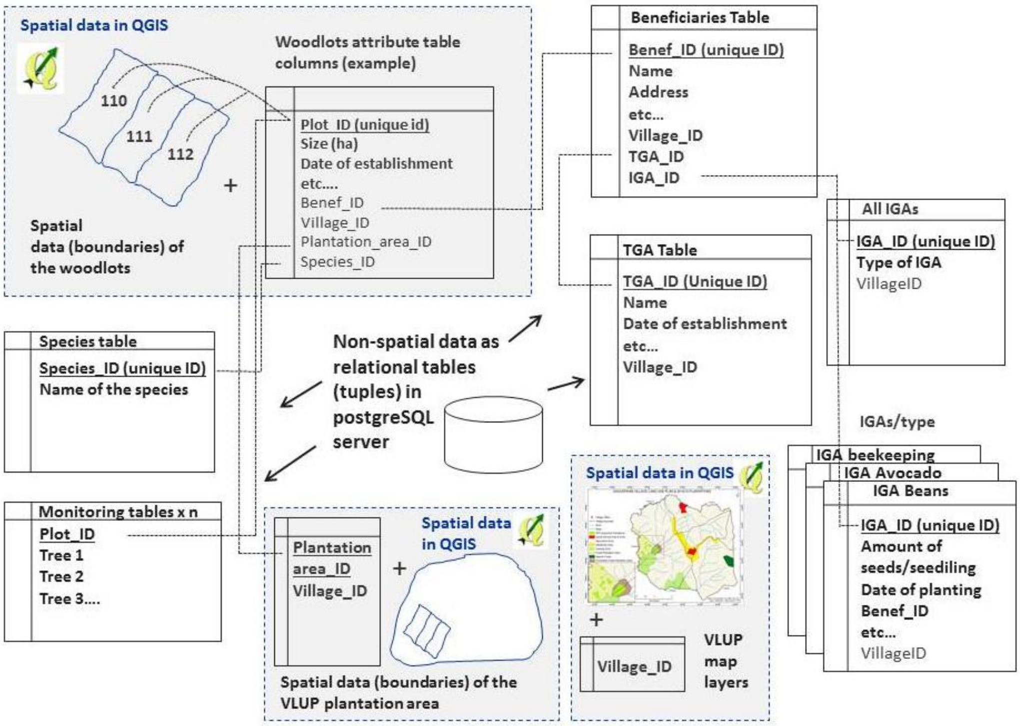
After the GPS track logs and WPs with ancillary information (sketch maps, notes, photos) reach the PFP office, the responsible person (Land use, GIS and ICT Expert) downloads the data, cleans the files and makes the plots spatially coherent data in GIS. This process should contain quality control of the information. First quality control takes place when the data is downloaded and opened in QGIS to observe the boundary consistencies and information of the woodlot owners. Overlaying WPs and track log in GIS will also show if the mapping process has succeeded.

Second quality control happens when the data sets are cleaned and edited in GIS to make the plot boundaries closed polygons with unique ID in a GIS. At this stage the boundaries are straightened and they are made to meet between the adjacent woodlots (sharing the same boundary, although in the field the boundaries are 5 m apart).

Once the spatial data is corrected, the plots can be copied into the woodlot database (one woodlot GIS layer, which contains all the mapped woodlots of PFP). In this procedure, each plot receives a new unique ID (running number). When the spatial transfer is successfully done, the attributes of the plot can be inserted. The core attributes are those, which describe unique parameters of the plots. Rest of the related tabular data is stored in a relation database which is linked into the core spatial data.

Majority of woodlot associated data will be in tabular form, i.e. as a collection of tables. This kind of linked tabular data can be managed in a FIS/GIS system when the system has support for relational database management (RDBM). In RDBM system the different tables are linked to each other by relational operators (e.g. plantation ID) for manipulating data in tabular form. RDBM system can include a spatial database extender, which adds support for geographic objects allowing location queries to be run in the system (i.e. links GIS with tabular data). (Figure 12)

Figure 12 The core spatial data consist of privately owned woodlots and attributes describing the properties of these plots. The rest of the tabular data is distributed into relational tables, which can be linked into the spatial data via common columns. Woodlots are associated to plantations areas in each PFP target village.



4.2.4 Plantation management and monitoring

At the moment the plantations established under the PFP are young and therefore easy to manage. The development of the plantations will vary depending on the site quality, possible damages, and management. As the plantations mature, field inventories are needed to monitor the condition and management status of the plantations. There is also a need to conduct inventories within the existing plantations which are established before the PFP to get an overview of their condition and management status.

Inventories are carried out through sample plot measurements, which are conducted periodically throughout the rotation. The data is collected at management unit level and includes, for example, tree survival rate, tree height, diameter, density and volume of the plantations. Based on the measurements, forest managers will be able to define the silvicultural treatments needed for producing high-quality timber (i.e. a management plan).

One of the main functions of the FIS for PFP is to provide an easy and reliable place to store and update the plantation inventory data. As discussed before, this data forms the basis of management planning and plantation monitoring and is essential for all functions of the FIS.

4.2.5 Geospatial analysis and visualization

In forestry, one of the most effective ways to visualize and analyse data is through maps. Therefore, most of the existing FIS solutions are built or linked to a GIS. Maps and geospatial analysis is needed throughout the PFP and beyond. For example:

- In planning, spatial analysis provides support e.g. for selecting areas for planting. When selecting suitable areas, information is needed on VLUPs, rainfall distribution, existing plantations, roads, and locations forest industries.

- In operational management, maps are good for distributing work instructions for field operators.
- Maps are also needed in monitoring and reporting. For example, data on the progress of plantation establishment becomes more informative if a map is presented along with the area figures.
- Maps provide an effective way to communicate within the programme and with relevant stakeholders.

One of the most important requirements for the FIS is a well-functioning GIS solution, where the geospatial data can be linked to other data sources. The FIS need to be able to store and process both vector and raster data coming from various sources. This means for example, topographical data (elevation contours, roads and rivers) as well as remote sensed data (satellite images, aerial photos, etc.).

4.2.6 Growth modelling and simulation

Forest inventory work is time consuming and requires a lot of resources. Therefore, sample plot measurements are often supported by growth and yield models, which predict the growth and development of the plantations. The growth of the trees is driven by various factors, including soil type, temperature, topography, and rainfall. The productivity of different growing areas is described through site indices or bonity classes, which are used to predict the potential growth speed of a plantation. Growth models are always developed by productivity class, and they vary from generic models to models that are localized utilizing data from the selected plantation area.

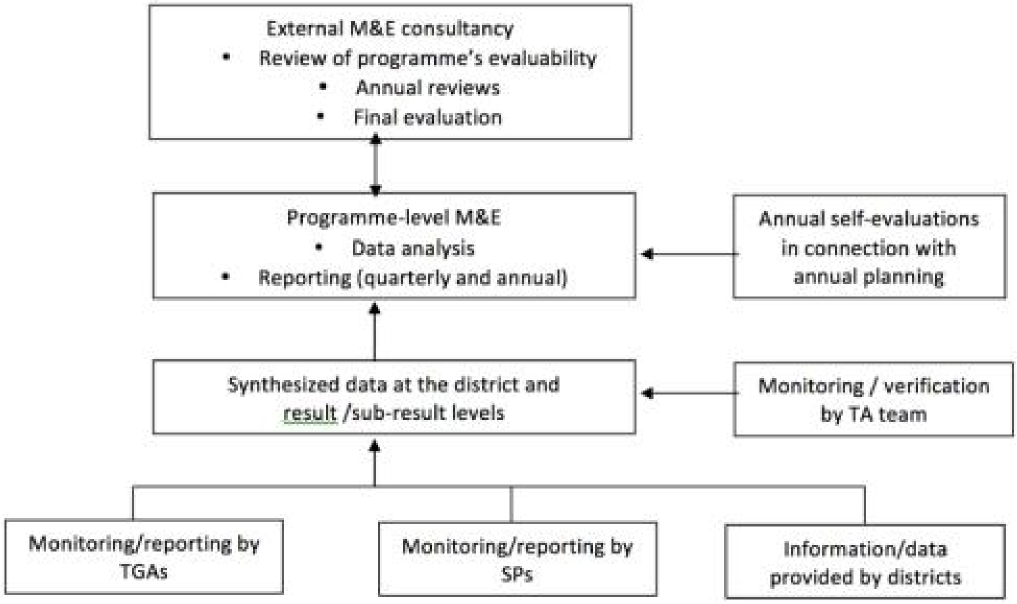
At this stage of the programme, there is no urgent need for growth modelling or simulations. However, according to the findings of the TGIS and IGA review conducted in May 2015, the tree growers are interested in seeing demonstrations of plantation cash flow analysis. This would help them to better understand how different management decisions affect the potential cash flows. This might also decrease the risk of harvesting pre-mature trees, as the growers would see how much more they could earn when applying optimal rotation. PFP could establish the profitability calculations for different species and management regimes. This would respond to the tree growers interest, and build their capacity to use profitability as one decision making factor in selecting species and regimes that are supported through the incentive scheme. Cash flow analysis would first require simulating the growth and harvesting volumes.

There are general growth models available for the main species planted in the PFP target area. Later on, the general growth models can be localized using the inventory data from the plantations. The data for the growth models is usually collected from permanent sample plots (PSPs), which are established in different growing areas. Simple growth modelling and simulations can be done using basic calculation tools (e.g. Excel). For more advanced simulations, more sophisticated tools are needed.

4.2.7 Monitoring, communicating, collaborating and marketing

Systematic data management is a prerequisite for good-quality monitoring. One of the key functions for a FIS during PFP is to support monitoring and evaluation of the programme. The current monitoring and evaluation framework of the PFP is described in Figure 13. Eventually, monitoring and evaluation will become part of the TGAs' and Apex body's work routines. Successful M&E requires well-defined procedures for data collection and storage, as well as user-friendly tools to process the data into meaningful information (performance statistics, maps).

Figure 13 Programme monitoring and evaluation system



Source: Programme Document

PFP also needs to distribute some of the key data to various partners and stakeholders, which requires the data to be in an easily understandable format (maps, graphs, etc.) and a channel to distribute the data. This could be done e.g. by linking the FIS to a web-map service, where the data could be shared to different user groups.

One of the goals of the PFP is to disseminate timber market information to relevant stakeholders and facilitating the development of market platforms and mechanisms. The development of the marketplace will support timber markets and increase transparency in timber trading. The FIS is expected to form the basis of the market platform. The key market data includes, for example, up-to-date average timber prices and information on the resources that are for sale. The resources can include both timber from harvestable plantations (thinnings and final fellings) and plantations that are for sale as a whole. The electronic marketplace established in Finland could be studied further to see whether a similar solution could serve the needs of PFP (see chapter 4.1.2, Box 3).

4.2.8 System requirements

The FIS solution of PFP is not a conventional FIS in the sense that PFP has many distributed geospatial tasks, which usually are not core data management processes of a FIS. These are for example the process of supporting VLUPs, making geospatial location-allocation analysis of possible plantations sites and making environmental impact assessments on the plantation development. When PFP activities are linked with similar actors and their plantation activities in the region (such as those of FDT and the forest companies), the requirements for shared FIS structures are even broader. There is a need that PFP makes such FIS solutions, which are able to adapt to changing conditions and demands and which are able to serve the key beneficiaries of the programme via Apex body, i.e. the private woodlot owners.

In practice the PFP geospatial data processing tasks, as they are described and anticipated in this report, rely on combined uses of different datasets from several sources. It is also evident that the quality of the data is not consistent and that geospatial decision support is needed at different spatial scales (local site related analysis as well as districts and regional scale strategical support). The FIS must be able to handle the core woodlot data set and the management of associated tabular data. Equally, the system should enable analysis of the baseline information of the existing forest plantations as well as many other environmental and infrastructural data. All and all, the FIS of PFP is more than forest information system. It is a broader constellation of geospatial information system with key FIS functionalities as well as other GIS functionalities to support the scope of PFP.

Eventually the FIS will have users at different levels. The directors need to produce and view reports, monitor the progress and make broader steering decisions of the FIS. Forest officers/managers use the system for long term/operative planning and field officers will be responsible for maintaining the forest inventory database. Woodlot owners and their representation in the Apex body need to benefit from the FIS by having better knowledge on the markets and management power over their property. Partners and stakeholders will have variable roles but at least their interest lies in viewing some key data of the resources. The different user levels and needs have to be addressed in the system design. This can be done by defining the different user levels and adjusting their ability to perform certain actions in the system (e.g. administrator, editors, and viewers).

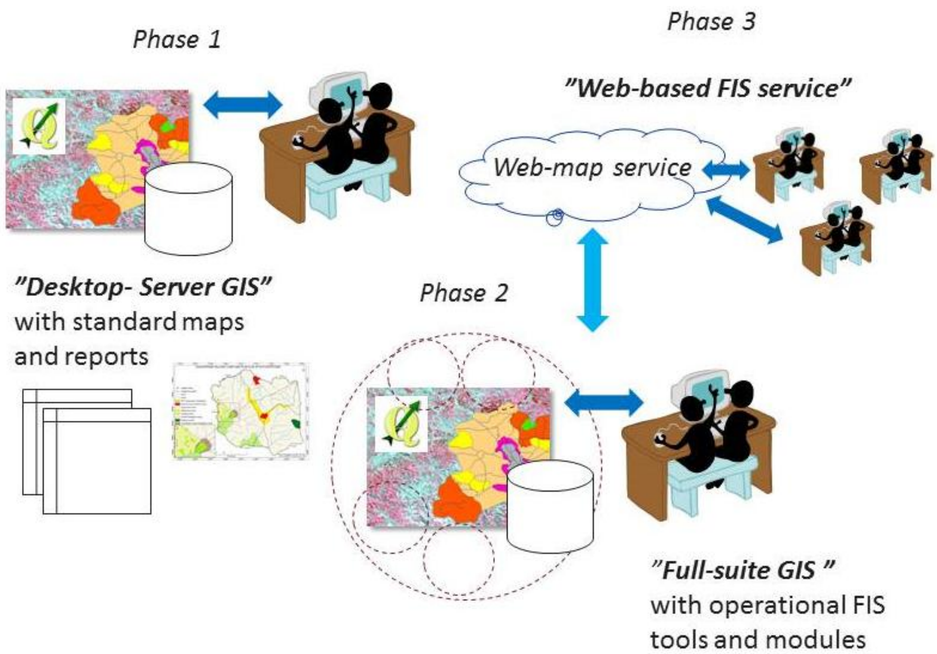
4.3 Plausible hardware and software solutions

With software solutions, the fundamental decision to be made is on whether to purchase a commercial system or start developing an Open Source system. The most well-known and therefore the most obvious commercial solution in Tanzania is Microforest. Some of the PFP staff has experience in using the system. In the FIS workshop held during the field mission, Green Resources delivered a presentation on the usage Microforest. The presentation was followed by a discussion on the pros and cons of Microforest. The outcomes of the discussion can be summarized as follows:

- Microforest is well-known and there is existing capacity to use it. The three biggest forestry companies in Tanzania are using the software (Green Resources, KVTC, and the New Forests Company). Tanganyika Wattle Company (Tanwat) has stopped using it due to the budgetary constraints.
- It is a ready-to-use solution and does not require initial investments on system development.
- The system is heavily dependent on external support (Syndicate), which causes delays in unexpected occurrences.
- In general, the usage of the system is considered to be relatively complicated, and it is not seen as a user-friendly solution.
- The cost of Microforest licence is high (USD 400 – 4 000 per month, depending on the planted area and license type), and therefore it is unlikely that such system can be sustained after the programme phases out.

Sustainability is one of the fundamental values of development projects such as the PFP. The most sustainable approach for building the FIS is to start gradually developing a system with freely available applications, and modify the system as requirements and users arise (Figure 14). This approach does not require high initial investment costs on system establishment (phase 1), but may of course require substantial investments later on when the system is tailored and especially used as a geospatial forest information service for beneficiaries and stakeholders in the region. However, if properly planned, the running costs of such system are low and the possibilities to gradually develop and improve the system are unlimited.

Figure 14 Gradual development of GIS/FIS from simple desktop-server GIS system (phase 1 left) towards full-suited GIS with FIS functionalities (phase 2, middle) and finally web-based FIS service (phase 3, right) can be done through controlled development phases over time (visionary example).



There are powerful open source software components for FIS, including GIS (and web-based applications), database management systems, web servers, and operating systems. For the FIS solution for the PFP, the most relevant include:

- **QGIS**, a GIS desktop application with data viewing, editing, analysis and visualization capabilities
- **PostgreSQL**, a powerful object-relational database system for tabular data management (Figure 15)
- **PostGIS**, a spatial database extender for PostgreSQL. Enables storage of both spatial and non-spatial data into a server environment
- **MapServer**, a platform for publishing spatial data and interactive mapping applications to the web. Enables distributed access to FIS. For example Geoserver (http://geoserver.org/)
- **Linux,** an operating system that is used especially in web-servers

Figure 15 PostGIS/PostgreSQL spatial database is the foundation of purely open source architecture for a FIS system

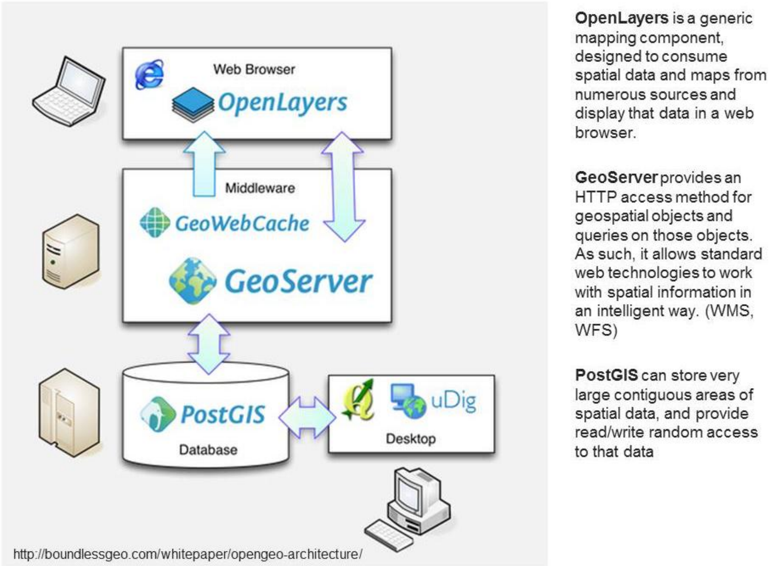
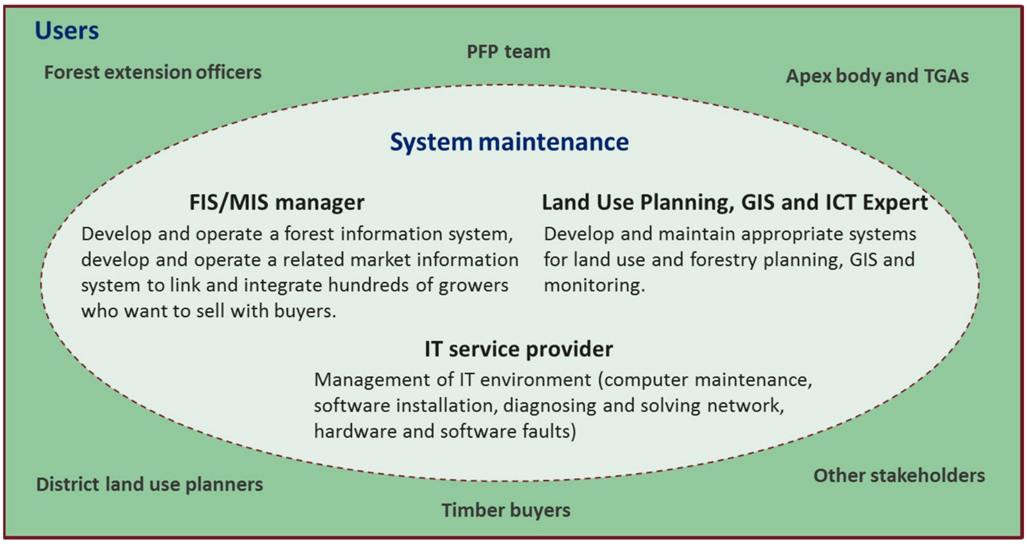


Figure from http://boundlessgeo.com/whitepaper/opengeo-architecture/.

4.4 System maintenance, development and costs

The initial development of the FIS will likely be outsourced. After the system has been set up, it will be maintained by a core team consisting of experts from the PFP and the Apex body. The programme is currently in the process of recruiting a Forest and Market Information Manager for the Apex body, who will eventually be in charge of maintaining the FIS. However, during the Phase I of PFP, the programme will have the main responsibility of maintaining and financing the FIS. It is important to bear in mind the aspects related to institutionalisation of the FIS throughout the system development. Otherwise, there is a high risk that the system will collapse once the PFP's support ends. Long-term institutional arrangements for the FIS have to be considered when designing the system. The foreseen users and maintenance of the system are described in Figure 16.

Figure 16 Possible users and maintenance of the Forest Information System



The maintenance of the FIS will handled by a core team consisting of a Land Use Planning, GIS and ICT Expert, FIS and Market Information System (MIS) manager, and IT service provider. The core team is responsible of the FIS/GIS system maintenance including data input, updating, management and analysis, and also training related to the extended FIS users.

The main users of the FIS are:

- **PFP team**, which monitors the progress of the programme and its result areas (TGIS, IGAs, VLUPs)
- **The Apex body and Timber Growers' Associations**, who utilize the FIS to monitor the plantation development and timber markets
- **Forest extension officers**, with responsibility of collecting geospatial data with GPSs of the plantations and collecting monitoring/inventory data
- **District land use planners**, with responsibility of making Village Land Use Planning maps
- **Timber buyers**, who are interested in available timber resources
- **Other users**, including TFS, FBD, etc., who will need to follow up on the general development of forest resources in Tanzania

One of the crucial factors of FIS success and sustainability is the competence/skills development of PFP and Apex body staff in using the system. While maintenance of the ICT infrastructures can be designated to key professional personnel, the critical asset in the long term sustainability comes from the users of the system. Without knowledgeable users, who appreciate the value of the FIS and understand how it practically influences the management of the forest resources, it is difficult to maintain and develop the system in the long run. Training and support to FIS users is very important.

The costs of a FIS can be divided in i) start-up costs ii) maintenance costs and iii) development costs. The start-up costs include hardware and software acquisition and initial investments in capacity development. The maintenance costs include the license fee (commercial systems), system maintenance support (provided by either internal support personnel or software developer company), and capacity development. Development costs refer to those investments, which enable the system to be transferred from desktop-server GIS gradually towards multi-user FIS service. At best, the last phase of the FIS would coincide technically with other spatial data infrastructures (SDIs), which the Government of Tanzania and other stakeholders in the region promote may choose to promote for fluent data sharing and assess of information. A good example of an open source SDI solution is the architecture of the Finnish National SDI, Paikkatietoikkuna, with its web map service (http://www.paikkatietoikkuna.fi/web/en). Experiences for best practices of OS information systems can also be found in Tanzania via the establishment of Zanzibar Land Information System (ZALIS) just recently. With strategically good choices, PFP may have substantial influence on the development of spatial and forest data systems in Tanzania.

The costs of commercial FIS solutions vary significantly. As a benchmark, the current price of Microforest software varies from USD 400 per month to USD 4 000 per month, depending on the planted area and acquired license type (Table 1). The Essentials license consists of basic features of Plantation Manager (PM) and Harvest Scheduling System (HSS), while the Full System license includes also the Business Suite and additional features of PM and HSS (also see Chapter 4.1.2, Box 1). The prices include support services through emails or telephone. The Full System license also includes two days of training per year.

Table 4 Current pricing of Microforest software (May 2015)

Planted Area (ha)		Monthly Rental (USD)	
From	To	Essentials	Full System
1	5 000	400	2 000
5 001	7 500	500	2 500
7 501	10 000	600	3 000

10 001	15 000	N/A	3 500
15 001	30 000	N/A	4 000

The indicative cost of Iptim, the other commercial FIS solution presented in Chapter 4.1.2, varies from 1 to 1.5 USD per hectare/year. This includes only the software license. Iptim+ package includes the software and a set of services to ensure the optimal use of the software and tailored support in tasks such as data integration, modelling, and the creation/validation of plans. Iptim+ license costs from 2 to 2.5 USD per hectare/year.

The costs of an OS based FIS solution are more difficult to estimate than those of commercial systems. As the software are free, the costs are related to system and capacity development. The development of an OS based FIS generally requires external expertise in some steps of the process. However, simple solutions, such as the one we initially recommend for PFP, will not require significant investments in system development nor in capacity building.

The hardware requirements of a FIS include the PCs (existing ones will generally do), a server, and related IT facilities. Regardless of the software solution, the hardware acquisition costs will remain on the same level.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Collecting and managing spatial and tabular data into a FIS database of PFP forest plantations

PFP has multiple data collection and production needs. The core geospatial data collection process is the mapping of the established plantations in the field by extension officers and creating plantation database in GIS for their continued follow-up, monitoring and management (1^{st} stage FIS). Both programme monitoring and the FIS to be developed will rely on the quality of the collected and stored data. The consistency and accuracy of the data defines the usability of the FIS, as the outputs can only be as good as the source data. If the quality of the data cannot be assured, there is a risk that the FIS will steer the project results monitoring and decision-making based on false assumptions.

Currently there are no written data collection procedures for PFP plantation data collection and data management in GIS and there exists no proper plans for further programme decision-making based on locational factors of the existing plantations, PFP established plantations and other environmental factors.

We recommend that the procedures related to core data collection of the programme are immediately standardised and forms of quality control are agreed and described. These include:

- Process of plantation boundary mapping with GPS
- GPS data processing into spatial data in GIS
- Plantation monitoring (inventory protocols)
- IGA data collection, and
- Plantation data management and sharing.

Ideally, the FDT and other actors in the area would have similar procedures and standards for data collection. This would enable merging of the different datasets in the FIS and better overall monitoring of the plantation forestry development in the region. Therefore, we recommend that different stakeholders are consulted when drafting the procedure descriptions (see Annex 6 for operational details).

5.2 Collecting other strategically and operatively important geospatial information

PFP needs many other supportive geospatial data sources to strengthen both strategical and operational decision making throughout the project results areas. Other critical data include infrastructure, location and quality of the existing forest plantations, topographic data, land cover and land use data and environmental data (habitats, biodiversity hotspots). There is plenty of existing geospatial data at regional scales available, but PFP needs to invest in new data/information production in one way or another. Either via analysis of existing supportive data sources, or perhaps even via purchasing of new data sets. It is cost-efficient to do such efforts preferably in collaboration or with the help of other actors and experts in the region.

We recommend that PFP makes a proper plan how the supportive spatial data will be gathered and at which spatial scale and level of detail the programme needs supplementary information. These data sets include especially:

- up-to-date information of the roads and other necessary infrastructure in the operation area of the programme (an PFP internal expert work)
- spatial information of the existing agricultural land uses, forest plantations and biodiversity-rich sites (as external expert work)

General information on the existing plantations (i.e. plantation baseline) is needed for planning, monitoring and marketing purposes. As the plantations are often small and scattered within a large geographical area, the most feasible way to collect the data is through remote sensing techniques.

The FDT has piloted an approach for plantation baseline mapping using Rapid Eye imagery (5 m resolution) and image classification techniques (Forestry Development Trust 2015). The outputs of the analysis are promising. If FDT decides to expand the analysis to cover the entire project area, it will likely serve the needs of PFP (assuming that the data is shared). It should also be acknowledged that purchasing recent Rapid Eye imagery across the whole study area benefits other data needs of PFP (land use and biodiversity mapping, VLUP existing land use map production). PFP needs to decide if shared order of the imagery and the production of the baseline via the piloted FDT methods is the best option. The downside of the FDT approach for plantation mapping is the high cost of not only the imagery (around 120 000 EUR) but especially consequent geospatial analysis, as the images need to be classified based on external expert work. Furthermore, the data of the baseline will need to be somehow updated and this may lead into repetitive data purchasing and analyses rounds.

We recommend the following steps to be taken by PFP (see Annex 6):

- PFP should (together with FDT) test alternative methods for forest plantation baseline mapping using existing “Open Foris” tools that were developed under the Food and Agricultural Organization of the United Nations (FAO)-Finland Forestry Programme, with funding from the govt. of Finland. As FAO has developed automated image classification techniques based on freely available satellite imagery, PFP and FDT should test if these methods bring substantially better results with Rapid Eye imagery and what are accuracy differences compared to Landsat Imagery. If both programmes have ground truthing data of the plantations, this should be used in the test.
- PFP (together with FDT) should consider if the above described wall-to-wall mapping is truly needed for the baseline information or it is sufficient to know approximate distribution and quantity of forest plantation resources within the programme area. Such information could also be established via visual interpretation of the existing freely available mid and high-resolution images and for example Open Foris Earth Collector. Some of the PFP staff have already received training in the use of the tools. Mr Anssi Pekkarinen, Senior Forest Officer, leads the development work and has indicated their will to support PFP in testing the tools in plantation mapping. If the results are good, PFP should continue training the programme and Apex body staff in using the tools.
- PFP (together with FDT) should test and compare Landsat OLI, Rapid Eye, and soon to be available Sentinel2 imagery capabilities in mapping land cover/land use, biodiversity areas in the region, and also test how well these images in relation to high-resolution Google and Bing imagery work for VLUP mapping process (see below).
- Regardless of the method, the accuracy level of remote sensing analysis will be insufficient for management planning. Small plantations are difficult to recognize from images and fieldwork is always needed for capturing the actual management status of the plantations. As fieldwork requires a lot of resources, collaboration between the different actors will be needed to properly map the location and status of the existing plantations.

5.3 Development of GIS support in VLUP process

Currently there are major deficiencies in the VLUP process, which decrease the quality and effectiveness of the VLUPs. This has resulted in a situation where the VLUP process is not effectively guiding the use of land in the villages. Although some of the problems are out of the scope of the PFP, there are critical issues that can be addressed by the programme that can significantly improve the VLUP processes.

We recommend that the PFP:

- Makes a proper training plan how to improve the skills levels of the district officers in their VLUP tasks related to use of spatial data and GIS and executes the plan as soon as possible to raise the overall quality assurance of the VLUP

- Uses the available financial resources to provide better spatial data for the mapping exercises of the VLUP (base mapping, existing land use mapping) and trains officers in the use of existing spatial data (see chapter 5.2 for satellite imagery discussion)
- Promotes awareness-raising of the communities on the process and benefits of VLUPs, including transparent village boundary verification practices.
- Strengthens the GIS operations within the VLUP process, especially by supporting village base map making before the VLUP intervention, and improving the overall visual quality of the VLUP maps.

5.4 Establishment of a FIS

Many of the core processes of the PFP are dependent on a reliable and user-friendly FIS solution. The programmes requirements for the FIS are manifold, and the system needs to able to adapt to changing conditions and demands of the users.

The design and functionalities of commercial FIS solutions are fixed to a large extent, and the system development is controlled by the software developer companies. In addition, the maintenance costs of the commercial systems (i.e. the license fees) are usually high.

We recommend that the PFP starts gradually developing a system with freely available OS applications, and modifies the system as new requirements and users arise. It is advised that that PFP immediately purchases a server, where the tabular relational data tables can be stored (PostgreSQL or PostGIS server) and establishes work protocols of spatial and non-spatial data input and management in this GIS-server environment. This system design is recommended to be designed by external IT expert in collaboration with the FIS/MIS manager just employed for the project.

The FIS and its development work have to be tightly integrated in the PFP work processes and have to facilitate the ordinary tasks of the users. Resistance to the system might occur if the users do not experience a personal gain when using the system. Needs based gradual development of the FIS will facilitate the buy-in of the system.

One of the crucial factors of FIS success and sustainability is the competence/skills development of PFP and Apex body staff in using the system. Without knowledgeable users, who appreciate the value of the FIS and understand how it practically influences the management of the forest resources, it is difficult to maintain and develop the system in the long run. Therefore, adequate training and support to FIS users is very important. We recommend that PFP makes a proper FIS training plan and starts systematic QGIS training of the key personnel and beneficiaries immediately. This training could be organized in collaboration with the other key actors in the region and it should focus of vocational training, which is as close to true work operations as possible.

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