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Stage 1 - Service Consolidation Actions of the Earthwatch GMES Services Element

Infrastructure Systems Analysis S10

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GSE Forest Monitoring

Infrastructure Systems Analysis S10

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It identifies demand driven growth paths for the European infrastructure. It analyses the capacities of the infrastructure elements and characterises key elements that need upgrade, potential new elements, and requirements for future EO missions.

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Executive Summary

This document *"Infrastructure Systems Analysis (S10)"* analyses the complete European service provision infrastructure that is necessary to deliver products and services from the GSE FM service portfolio.

It identifies demand driven growth paths for the European infrastructure. It analyses the capacities of the infrastructure elements (space, service, user and in-situ) and characterises key elements that need upgrade, potential new elements, and requirements for future EO missions.

This analysis is based on the inventories and scenarios provided by the *"Precursor Systems Inventory (S9)"*, *"Data Sources Inventory (C10)"*, *"Data Needs and Availability Prospectus (C12)"*, and the *"Operational Services Scenario (C11)"*. It is consistent with the *"Strategic Plan (S1)"* and the *"Service Prospectus (S3)"*.

The main results and conclusions of the *"Infrastructure Systems Analysis"* are:

(1) Space Infrastructure

(a) EO space segment and data supply:

- Long term continuity of EO satellite missions: The GSE FM services require a long term perspective of EO data provision to justify the adaptation of the users' infra-structure to using EO services. The long term continuity of the EO data as main data source for the GSE services must be guaranteed. GMES is totally depending on the maintenance of EO systems and on their upgrade and/or replacement over time. Follow-on missions and upgrading of sensors have to be planned within long term continuing satellite programs.

- The planned sentinel missions of ESA, especially the realization of the envisaged super-spectral imaging family (continuity of Landsat data type), are of great importance for the GSE FM services. To ensure continuity of Landsat data Europe has to build up own capacities and/or closely cooperate with U.S. for the implementation of the Landsat Continuity Mission.

- Lack of timeliness and insufficient frequency of EO observations with optical sensors: The critical problem for optical data is the availability of cloud-free data over a certain region at a defined time period. Due to cloud coverage, it is necessary to have a more frequent coverage with EO data by increasing the revisit frequency. This could be done by either (a) a satellite configuration with several identical satellites on the same orbit or (b) a satellite configuration which integrates several satellites into a harmonised system and/or (c) satellites with high spatial resolution and significant larger swath width (single instrument or two instruments in twin mode) to increase revisit time considerably. For large area mapping and monitoring the data should be always acquired in nadir on a regular fixed overpass schedule.

- Redundancy and backup capability of EO missions: The current problems with Landsat 7 clearly show the urgent requirement that EO missions need redundancy and backup capabilities. For operational service provision it must be ensured that in case of technical problems with a single satellite or even the loss of satellites this data gap can be compensated without any time delay.

- Integration of new missions, especially those operated by national agencies of the member states, e.g. Pleiades, Cosmo-Skymed, TerraSAR-X, and Rapid Eye.

- Long-term continuity also requires the setting up of institutional and commercial funding mechanisms, which means that the funding for these operational systems has to be shifted from the research and development domain to budget lines in the institutional or commercial funding framework.

(b) EO ground segment:

- "Extended Ground Segment Capabilities": According to the infrastructure analyses and the results of the 3rd co-location meeting there is a strong need to extend the current role of the ground segment in order to enhance the productivity and relieve the present burden on service providers by:

  - Generating baseline products by *standardized geometric and radiometric pre-processing*. This includes ortho-correction as well as radiometric calibration and atmospheric correction in a highly standardized and reproducible manner. A similar approach has been successfully used in the CLC2000 / Image 2000 project and should therefore be extended to further sophisticated pre-processing capabilities.

  - Generating and providing *commonly accessible data pools*, which are used by several GSE services. For all land related service this is especially needed for Digital Elevation Models (DEM). The generation and consistent archiving of a European or global DEM with high resolution as a horizontal activity for several GSE services would considerably improve the quality and homogeneity of the GSE products.

  - Generating *basic value-adding* products, e.g. generic land cover and land cover change products according to or similar to the CLC nomenclature.

  - Establishing interfaces and links to the non-EO components needed for GSE services, e.g. the INSPIRE initiative for the European spatial data infrastructure or other relevant user and in-situ data bases.

- Harmonisation of the European data acquisition: Currently, the EO data acquisition is not harmonised; for each satellite system different organisations are responsible. Thus, the data acquisition policies are ruled by quite heterogeneous goals. A harmonised data supply by a European “Integrated Ground Segment” is desirable from the viewpoint of the GSE service portfolio.

- Adaptation of the existing EO ground segment to the new or follow-on missions, which are relevant for GSE FM. This includes investments for the data acquisition, processing and archiving infrastructure. Furthermore, cooperation schemes have to be elaborated, especially for the missions operated by national agencies.

(2) Service Infrastructure

- For the time frame until 2004 (0-2 years) the existing service infrastructure elements provide sufficient performance, reliability and capacity to produce the GSE FM services for the current core users.

- On medium (2-5 years) and longer (5-10 years) term the existing service infrastructure elements are not sufficient to provide the services in future and up-scaling is necessary. The upgrading of the service infrastructure is not limited from a technical point of view. However, for the geographical enlargement of the GSE FM services a distributed operational infrastructure of service providers is needed with specific regional knowledge and more efficient production chains have to be implemented.

- A bottleneck for the increase of production is the availability of ancillary data, e.g. topographic maps, forest base maps, or digital elevation models. This is especially true for areas out of Europe. Without such information it is not possible to produce the complete suite of services, especially in higher scales. Thus, it is recommended to investigate the possibility to provide such basic ancillary information from other sources, in order to achieve more independency from existing data sources such as public survey institutes. For that two possibilities exist: (1) to produce all data by upgrading own capacities (e.g. by integration of field survey or airborne data within multi-phase / multi-stage inventory concepts), or (2) ancillary data may be procured from external sources such as specialised service providers. Although this would increase the production cost it will assure that even in case of current unavailability of model and ancillary data from public sources delivery of services is possible, world-wide.

- The above mentioned concept of “extended ground segment capabilities” at well equipped processing centres with high throughput capabilities will disburden service providers and enable the establishment of efficient production chains based on a network of distributed service providers.

(3) User and In-situ infrastructure:

For the time period 0-2 years:

- In general, the infrastructure elements at the core users are quite heterogeneous and at the user community at large; the dependency on the availability of auxiliary data is high. GIS and database software are available at the core users. National forest inventories are being performed in most European countries; some countries have regional forest inventories with a different methodology for each region. ICP Forests concerns a European wide forest inventory following a standardised methodology. In several countries the plots used for this inventory are also part of the national forest inventory. In other countries the ICP Forest inventory is independent from the traditional national forest inventory. The used software consists of GIS and remote sensing tools, statistical and data base software, and, only for few cases, proprietary software.

- No necessary upgrades and new elements are foreseen necessary for implementation of the infrastructure for GSE FM services. Some Eastern European countries do not have high penetration of broadband Internet access, but other means may be more suitable for the transport of large amounts of data. In some particular cases there may be a need for upgrade of hardware and software to be able to fully use the information products that GSE Forest Monitoring can provide.

- National forest inventory data is currently stored in databases that come in a wide variety of formats and architecture. It would be beneficial to GSE Forest Monitoring if these systems could converge. In the short-term future, the objectives of the EC EFICN Regulation could contribute to the improvement of this issue.

For the time period 2-5 years and 5-10 years:

- To ensure further growth, it will be necessary that the infrastructure of the end-user-organisations will be able to handle the GSE Forest Monitoring products and to integrate the products in the users' working environment. It is expected that the penetration of broadband Internet access will increase in the whole European Area. This will allow better interactivity with the end users. This would also enhance possibilities for bi-directional web-based data exchange.

- Requirements towards necessary infrastructure and data sources will in the longer term evolve in parallel with technological capacity of (among other but mainly) Earth Observation sources. Higher resolution coverage, increase of temporal resolution may put higher demands to the user infrastructure.

- It is not foreseen that there will be over-capacity of infrastructure elements. A likely option is that different national and supra-national (EU) monitoring schemes will show increased degree of convergence.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ASAR	Advanced Synthetic Aperture Radar
CLC	CORINE Land Cover
CLRTAP	Convention on Long-Range Transboundary Atmospheric Pollution
COST E21	European Cooperation in the Field of Scientific and Technical Research; E21: Contribution of Forests and Forestry to Mitigate Greenhouse Effects
DEM	Digital Elevation Model
DOP	Digital Ortho Photo
EC	Commission of the European Communities
ENVISAT	ENVIronment SATellite
EU15	European Union of the fifteen Member States
EO	Earth Observation
ERS	European Remote Sensing Satellite
ETM+	Enhanced Thematic Mapper
EU	European Union
FIMCI	Forest Intensive Monitoring Co-ordinating Institute
GCP	Ground Control Point
GIS	Geo-Information System
GMES	Global Monitoring for Environment and Security
GPS	Global Positioning System
GSE	Global Monitoring for Environment and Security - Service Element
GSE FM	Global Monitoring for Environment and Security - Service Element Forest Monitoring
ICP Forests	International Cooperative Programme on assessment and monitoring of air-pollution effects on forests operating under UNECE
HI	SPOT-5 Multispectral data with 10m resolution (includes MIR band)
HRG	SPOT-5 Sensor

HRV	SPOT 1-3 Sensor
HRVIR	SPOT-4 Sensor
IRS	Indian Remote Sensing Satellite
JERS	Japanese Earth Resources Satellite
LC / LU	Land Cover/ Land Use
LISS	Line Imaging Spectrometer Sampler
LU	Land Use
LUC	Land-Use Change
LUCAS	Land Use and Cover Areal Survey
MIR	Middle Infra Red (1.5µm band)
MS	Multi-spectral
NAS	Newly Associated States
NCC	National Coordinating Centre
NFC	National Focal Centre
NFI	National Forest Inventory
NIR	Near Infra Red
PAN	Panchromatic
PCC	Programme Co-ordinating Centre
SPOT	Satellite Pour l'Observation de la Terre
SRTM	Shuttle Radar Topography Mission
TBFRA	Temperate and Boreal Forest Resources Assess
TM	Landsat Thematic Mapper
XI	SPOT 4 Multi-spectral data (includes MIR band)
XS	SPOT 2-4 multi-spectral data
UN	United Nations

1. Objective and Scope

This document analyses the complete European service provision infrastructure that is necessary to deliver products and services from the GSE FM service portfolio.

It identifies demand driven growth paths for the European infrastructure. It analyses the capacities of the infrastructure elements (space, service, user and in-situ) and characterises key elements that need upgrade, potential new elements, and requirements for future EO missions.

This analysis is based on the inventories and scenarios provided by the *"Precursor Systems Inventory (S9)"*, *"Data Sources Inventory (C10)"*, *"Data Needs and Availability Prospectus (C12)"*, and the *"Operational Services Scenario (C11)"*. It is consistent with the *"Strategic Plan (S1)"* and the *"Service Prospectus (S3)"*.

2. Method of Description

On the basis of the *"Strategic Plan (S1)"* and the *"Operational Services Scenario (C11)"* the services and their growth scenarios are analysed. Starting from the results of the *"Precursor Systems Inventory (S9)"* demand-driven growth paths and upgrades for each of the infrastructure elements are derived. Because infrastructure elements are closely related to the data needs of the services, this analysis is done in accordance with the *"Data Sources Inventory (C10)"*of existing data and the *"Data Needs and Availability Prospectus (C12)"* for future data sources.

The analysis is grouped according to the three relevant infrastructure systems: space, service, user and in-situ infrastructure. The growth paths are derived on short, medium and longer term for the time scales 0-2 years, 2-5 years, and 5-10 years.

3. Analysis of Services and their Growth Scenarios

Based on the "*Strategic Plan (S1)*" and the "*Operational Services Scenario (C11)*" it is expected that there will be a significant growth of GSE FM services. In general, the growth on medium term (2-5 years) will be most dynamical in Europe, and on longer term (5-10 years) world wide. As a result from the detailed analyses done in the "*Operational Services Scenario (C11)*", the current service areas and the regions for service growth are shown in Fig. 1 as an overview.

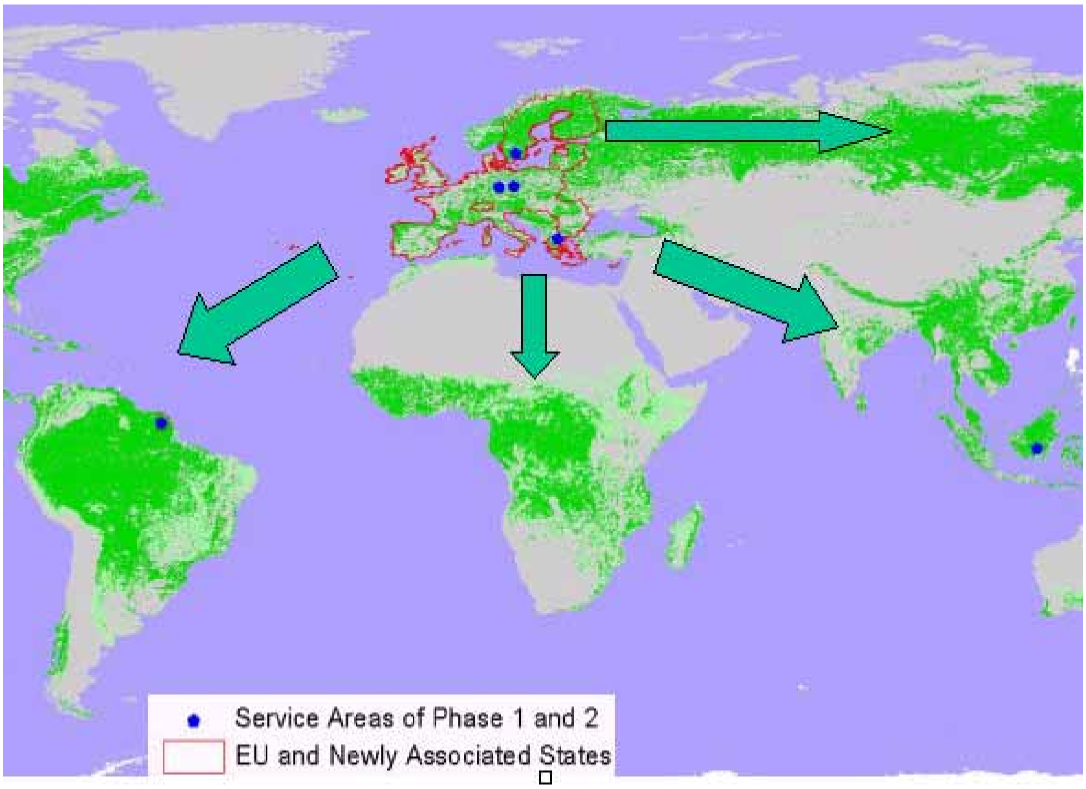


Fig. 1: GSE FM Services and their world-wide growth

In best-case scenario it is assumed that the following mapping area will be covered by GSE FM services:

Tab. 1: Mapping area per period (Mio sqkm)

	2003-04	2005-07	2008-12
National Greenhouse Gas (GHG) Reporting	0.141	1.46	5.89
Clean Development Mechanism (CDM) Projects	0.024	0.16	0.49
Mapping and Monitoring of Disturbances	0.035	1.55	6.02
Sub-National Forest Information	0.016	0.10	1.83
Land Cover and Forest Indicators	0.040	1.55	6.86

This analysis resulted into detailed estimates of mapping areas for each of the GSE FM services, which have derived in detail in C11.

4. Ability of Infrastructure to Meet Requirements at Present

4.1. Space Infrastructure

4.1.1. Existing Infrastructure and Data Sources

Based on the results of the "Precursor Systems Inventory (S9)" and the "Data Sources Inventory (C10)" the following main conclusions for the existing EO infrastructure and EO data sources in the consolidation phase (2003-2004) can be drawn:

- All current GSE FM services rely on EO space and ground infrastructure with high operational availability and throughput of the EO ground segment and well established satellite programs like the Landsat, SPOT, IRS and ERS/ENVISAT missions.

- The current European ground segment with the ESA Earthnet stations, the CNES SPOT ground stations, the Euromap IRS ground segment and the ESA ERS and Envisat ground segment provides the basis for the GSE FM EO data supply. Moreover, international EO ground infrastructures outside Europe are used.

- The current technical faults of Landsat 7 impose severe problems on several of the GSE FM services. Landsat 7 ETM+ has been reactivated since October 2003, however with significantly reduced image quality due to the faulty Scan Line Corrector (SLC). These anomalies in the resulting data massively limit the usefulness of Landsat 7 data or even make it unusable for the GSE FM services.

- A critical problem for optical data is the availability of cloud-free data over a certain region at a defined time period.

- Data costs differ depending on the sensor. The price policy of the Landsat program, which offers the data at COFUR (costs of fulfilling user request), has in general led to a significant increase in the use of EO data.

4.1.2. Capacities and Performance

- The existing European ground infrastructures provide sufficient acquisition and processing capacity to supply the current services with the necessary EO data.

- Data ordering, production and delivery are highly operational, mainly based on internet user interfaces.

- The EO archives are well accessible via internet. However, in general the data coverage (temporal and geographic) is not systematic.

4.1.3. Necessary Upgrades and New Elements

- The most critical issue is currently the Landsat 7 data supply. The Landsat 7 problem show that it is important that the services must be adapted to allow as much flexibility as possible in EO data input and to enable the replacement of one EO data input (standard data source) by alternative EO data sources.

- The European data acquisition is not harmonised; for each satellite system different organisations are responsible. Thus, the data acquisition policies are ruled by quite heterogeneous goals. A harmonised data supply from an integrated European ground segment is desirable from the viewpoint of the GSE service portfolio.

4.2. Service Infrastructure

4.2.1. Existing Infrastructure Elements

The existing Service Infrastructure elements have been identified and described in S9. Tab. 2 summarizes the relevance of these elements to the updated 5 GSE Forest Monitoring Service Packages.

Tab. 2: Existing Service Infrastructure elements and their relevance to the GSE FM Portfolio V2 (bold marked: most relevant Infrastructure element for service portfolio)

	Nat. GHG	CDM	Disturb.	Sub-nat.	LC&FI
CORINE Land Cover 2000	X	X		X	
Land Use Clutter Mapping	**X**	X		X	
Land use Mapping Geoapikonisis	**X**	X		X	
Land Cover for CDM	X	**X**		X	
Sub national Forest GIS Update	X			**X**	X
Forest Control System Sweden			**X**		
Forest Cover Map using SAR data	**X**		X	X	X
Forest Area & Biomass using high-resolution Optical data	**X**		X	X	X

The general conclusions of the Service Infrastructure Inventory with respect to the service requirements at present are:

- Most of the identified Service Infrastructure elements (at least their components) are in a pre-operational or operational status, but with different maturity. Standardized work-flows and process chains are established; interfaces seem to be well defined.
- None of these Service Infrastructure elements is an operational “service system”: information is produced on project level mainly. There is a high amount of management (e.g. for team coordination, establishing production): Data procurement and pre-processing is specific to each of the “project”; the up-date rate is in most cases low (e.g. CORINE).
- Some components of Service Infrastructure elements (e.g. interpretation and validation) are characterized by a high amount of manual and interactive work. This leads to bottlenecks in the process chains and to reduction of service performance.

The following chapter will compare the capacities and performances of these existing Service Infrastructure Elements to the requirements of the Operational Scenarios (C11 V2). The analysis refers to the effective mapping area per service (C11 V2, table 18).

4.2.2. Capacities and Performance

Tab. 3 gives an overview of the current capacities and performance measures of existing Service Infrastructure elements. The Service Infrastructure element is not identified as an element of the current service provision. Thus, it will not be considered as such, but as an important input data source. Nevertheless, the approach of CORINE Land Cover production can be used as an example for the exploitation of service production.

In comparison, Tab. 4 figure out the capacities needed for service production in 2003-04 (with respect to the Operational Service Scenario C11 V2, table 18 – effective mapping area per service).

Tab. 3: Current capacities and performance measures of existing Service Infrastructure elements

Service Infrastructure element	Current Capacity	Performance measures - Staff	Performance measures - Software
CORINE Land Cover 2000	1 survey per 10 years ~3 years for 15 EU member states and NAS countries		
Land Use Clutter Mapping	~70,000 km² / month	18 image processing, 1 PM, 1 technical coordinator, 1 GIS specialist)	2 COTS IP licenses 1 COTS GIS license 18 application software licenses
Land use Mapping Geoapikonisis	~30,000 km² / month	6 image processing, 2 ground data collection, 1 PM, 1 technical coordinator, 1 GIS specialist	
Land Cover for CDM	~ 50,000 km²/month	4 image processing specialists	
Sub national Forest GIS Update	Federal State Thuringia (16172 km²)/ 6 months	1 image processing specialist, 1 PM	1 COTS IP license, 1 COTS GIS license
Forest Control System Sweden	1 scene per day (Landsat: 30,000km², SPOT: 2500 km²)	2 image processing specialists, 1 PM, 1 GIS specialist	2 COTS IP licenses 1 COTS GIS license 2 application software licenses
Forest Cover Map using SAR data	~30,000 km²/month	4 image processing specialists	
Forest Area& Biomass using high-res. Optical data	~50,000 km²/month	4 image processing specialists	

Tab. 4: Capacities needed for service provision with respect to effective mapping area per service 2003-04

Service Package	**Capacity needed [km²/year]**	**Service Infrastructure element**	**Capacity available [km²/year]**	**Comment** (overcapacity: ➚; under-capacity: ➘)
Nat. GHG	141,000	Land Use Clutter Mapping	840,000	➚
Nat. GHG	141,000	Forest Cover Map using SAR data	~360,000	➚
Nat GHG	141,000	Land use Mapping Geoapikonisis	~360,000	➚
CDM	24,000	Land Cover for CDM	~ 600,000	➚
Disturb.	35,000	Forest Control System Sweden	~365 scenes (Landsat: 360,000, SPOT: 30,000)	➚
Sub-nat.	16,000	Sub national Forest GIS Update	~32,000	➚
LC&FI	40,000	Land Use Clutter Mapping	840,000	➚

In 2004, the capacity of existing Service Infrastructure element is sufficient to meet the capacities required for service provision.

4.2.3. Necessary Upgrades and New Elements

In general, replacement and new elements are not needed. Upgrades should include the optimisation of Service Infrastructure elements, e.g.:

- Improvement of processing chains
- Improvement of automated production steps
- Standardization of work-flows
- Optimization of data procurement and data-flows
- Improvement of QA measures

4.2.4. Existing Model and Ancillary Data Sources

A first analysis of the data sources necessary for service provision is included in the Data Sources Inventory C10 (table: 59, page 80). This has been further elaborated in the Data needs and Availability Prospectus C12.

The ability of model and ancillary data sources to meet the service requirements depends on the following constrains:

- Existence of data sources in the relevant service areas
- Up-to-date information to assure timeliness and quality of the services
- Accessibility of data sources, legal framework for access and use.
- Standardization of data sources with respect to formats/interfaces and content

One of the basic assumptions for the operational service scenario in the time frame of 0-2 years is the availability of data sources needed for the service provision (see C11). Two cases of service growth scenario have to be considered:

- The provision of services will be closely linked to the existing service areas and core users:
  Services will build on existing and accessible data-sets commercially available or provided by users.
  - ➢ DEMs, Topographical Maps, land use information, forest inventories: use of same data sources as used during precursor service provision
- The provision of services will be extended to additional service areas and users: Services cannot build on data sources used for precursor service provision.
  - ➢ The impact on the model and ancillary data sources will be similar to the mid- and long-term perspective described in chapter 7.

4.3. User and In-situ Infrastructure

4.3.1. Existing Infrastructure and Data Sources

The Precursor Systems Inventory revealed that a number of service provision facilities or service elements already exist that could be assembled or scaled-up to contribute to the GSE service infrastructure. The most relevant precursor systems are grouped into three categories (1) Land Use and Land Use Change Mapping, (2) Sustainable Forest Management and Control Systems, and (3) Forest Inventory Systems. The main results are summarized below.

With respect to the Product Families *OM* (Ortho Image Mosaics, Ortho Images), *LU* (Land Use), and *LUC* (Land Use Change) the precursor elements of the category "Land Use and Land Use Change Mapping" are important. The most relevant system is the European wide mapping project CORINE Land Cover 2000, where almost all European countries are participating. The mapping is based on a common methodology and an identical nomenclature with respect to the land use classes all over Europe. The nomenclature is standardised and the mapping is performed at distributed facilities all over Europe according to a common methodology.

With respect to the Product Families *FA* (Forest Area Map), *FT* (Forest Type Map), *FAC* (Forest Area Change), *CC* (Clear Cut Mapping), and *CS* (Volume, Biomass and Carbon Statistics) the precursor elements of the category "Sustainable Forest Management and Control Systems" are relevant. Precursor elements exist for all of these products, however with different maturity and operational characteristics.

European-wide and in the 'developed' world in general, countries have well-established operational forest monitoring systems in place and forestry data are up-to-date (only 2% of the forest area in Europe and North America is covered with data of more than 10 years old). Most inventories follow a periodicity of 10 years or longer. Periodicity here means the number of years between the inventories of a singular administrative entity, like e.g. a province. Concerning survey methodology in Europe and North America, 25 % of the forest area is monitored with field sampling and 75 % is monitored by means of stand inventories.

In developing countries, the situation is often different. In the year 2000, in the African region, for 66 % of the forest area the time to the latest forest inventory was more than 10 years and for 17 % of the forest area more than 20 years. In the other regions, the time to the last forest inventory was in the year 2000 maximum 15 years. Latest forestry data was between 10 and 15 years old: for 29 % of forest area in Asia & the Pacific, for 83 % of forest area in Latin America & the Caribbean and for 45 % of the forest area in Western Asia. Availability of and access to in-situ data can be a problem in the countries concerned. For more detailed info is referred to Annex A of the GSE-FM document 'Key User Segment Profiles'. Concerning survey methodology, expert estimates and detailed mapping are often the main sources of information. No information was compiled however on the methodologies, standards and definitions valid for the category 'detailed mapping' (FAO, 2001 and UN, 2002).

With respect to the Product Families *FEI* (Forest Environmental Indicators) currently no relevant precursor systems could be identified.

In general, the infrastructure elements are quite heterogeneous at the core users and at the user community at large; the dependency on the availability of auxiliary data is high.

GIS and database software are available at the core users (except for the Russian core user). One of the objectives set by the United Nations Agenda 21 process at the Earth Summit in Rio in 1992 was the implementation of a GIS-based soil information system for the digital capture of land data, showing the status and processes of change of land resources, including soils, forest cover, wildlife, climate and other elements (UN, 2002). A 10-year review of Agenda 21 revealed that reportedly such system have been implemented in 28 % of countries and that it is under progress in 13 % of countries worldwide. When taking into account the forest area per country, than in Europe (including the Russian Federation) and North America, 97 % of the forest area is within countries that are or will be covered with a GIS-based soil information system. In Asia and the Pacific and Latin America and the Caribbean, respectively 89 % and 80 % of the regional forests are within countries where such system already exists or is under progress. In Western Asia only 46 % of the region’s forests would be covered and in Africa only 17 %. For more detailed regional and country-wise information, is referred to Annex A of the GSE-FM document ‘Key User Segment Profiles’.

National forest inventories are being performed in most European countries; some countries have regional forest inventories with a different methodology for each region. ICP Forests concerns a European wide forest inventory following a standardised methodology. In several countries the plots used for this inventory are also part of the national forest inventory. In other countries the ICP Forest inventory is independent from the traditional national forest inventory. The used software consists of GIS and remote sensing tools, statistical and database software, and, only for few cases, proprietary software.

For in-situ observation data sources, the Data Sources Inventory has shown that most necessary input data are available from national forest inventories and from ICP forests. All considered data sources are currently operationally available, except for the EU LUCAS land survey and COST E21, which will be completed in the near future.

The national forest inventories basically operate with a higher plot density than ICP forests. National forest inventories on grids of (0.5 km x 0.5 km) to grids of (9 km x 9 km); the ICP Forests Level I survey is performed on a 16 x 16 km transnational monitoring grid. Wider grids (16 km x 32 km or 32 km x 32 km) were applied in boreal areas and in maquis area (Haußmann et al., 2000). The advantage of ICP forests is a collection of data according a harmonised, homogenous set of definitions and methodology; the underlying definitions of variables in national forest inventories are similar between countries but not always the same.

For data from national forest inventories the updating is done generally at 10-years intervals. The ICP Forests data set is collected yearly. ICP Forests member countries generally assess and report annually to the ICP secretariat. The time-scale of data availability may be of importance especially to the national forest inventories that have been performed in many countries for decades. However, the methodology has changed a lot in the last two decades due to the general availability of orthophotos and remote sensing data. Inventories for ICP forests have started in 1986 for level I and in 1992 for level II.

With respect to the access conditions, it can be stated that raw forest inventory data that can be linked to a specific place by high precision coordinates are not publicly available due to the protection of private information of (mainly) private forest owners. Such data can in most cases be made available for the purpose of scientific research but under strict conditions, at no costs. Otherwise costs for extraction of data from the database and preliminary analysis usually have to be reimbursed. The aggregated forest inventory results are usually accessible to the public by means of (hardcopy and electronic) reports. Russia is exceptional in that case due to the state security regulations for large scale geographical data. Most raw forest inventory data could be obtained, however not in geo-referenced form.

The most specific data sources are the land cover/land use data. CORINE Land Cover is the only homogeneous data source available spanning the integral territory of the European Union (‘from wall to wall’). Forest cover maps and other forest related data sources (e.g. forest management plans) are specific to the local or regional situation and often provided by users. Thus, the availability in other regions cannot be guaranteed. In addition, these data sources need a short-time update rate to assure the quality of services.

Much less is documented about the availability of forest inventory data in countries outside the European area.

Special project-based forest inventories will probably be necessary for the monitoring of CDM projects. GSE Forest Monitoring should establish guidelines, which the client should follow when performing the inventory. These guidelines should be based on the special guidance by the CDM Executive Board on the monitoring of small-scale CDM projects.

4.3.2. Capacities and Performance

Most forest policies and forums require information updates at shorter intervals than at which forest inventories are repeated. In practice, countries’ reportings that fall within a singular inventory period may however vary, because of updates of information at completion of the inventory of sub-national entities, or through extrapolation or modelling based on historical trends. Some countries may consider such approach not sufficient for the reporting for e.g. the Kyoto Protocol, which in particular sets very high standards to the required information. Extrapolation and/or interpolation of data do not provide the best means for provision of accurate data. Earth Observation could allow bridging the time-gap between in-situ forest inventories and publishing of timely and accurate data at e.g. yearly intervals as will be required for the Kyoto Protocol.

Methodological differences between countries' collection procedures of national forest inventory data, cause that the data are not perfectly comparable. Current approaches to improve data comparability include scaling of national data with conversion factors to fit it with the international (FAO) definition for forest and other variables as applied for the UNECE/FAO Temperate and Boreal Forest Resource Assessment. There already exists a framework in which different European countries collect forest inventory data according a uniform methodology, namely ICP Forests. The functioning of ICP Forests is now largely influenced by the (EC) Council Regulation (2152/2003) "Forest Focus", which will continuously put attention to improving the collection and harmonization of data. Earth Observation could be a major contributor in the process of collecting homogenous data according standardised methodology and definitions in- (and outside of) Europe.

In most if not all countries, the regional or national forest authority prepares data and information contributions to (regional, national and international) reportings in cooperation with the responsible ministry. Most forest authorities have in-house capacity and experience with GIS and Earth Observation. However an increased use of such data needs to go along with sufficient training of staff.

Most of necessary data is suitably covered by existing national forest inventories. Biomass expansion factors and carbon conversion factors are becoming available with high accuracy but still need more regional detail and diversification of the tree species coverage.

In countries where forestry is managed under a regional authority, a national focal point with clearly defined mandate would be a must for efficient communication. A good organisation of and between national focal points, that is responsible for the different policies within the scope of GSE Forest Monitoring, would also increase efficiency.

4.3.3. Necessary Upgrades and New Elements

No necessary upgrades and new elements are foreseen necessary for implementation of the infrastructure. Some Eastern European countries do not have high penetration of broadband Internet access, but other means may be more suitable for the transport of large amounts of data. In some particular cases there may be a need for upgrade of hardware and software to be able to fully use the information products that GSE Forest Monitoring can provide.

National forest inventory data is currently stored in databases that come in a wide variety of formats and architecture. It would be beneficial to GSE Forest Monitoring if these systems could converge. In the short-term future, the objectives of the EC EFICN Regulation could contribute to the improvement of this issue.

5. Growth Paths for Space Infrastructure

Based on the scenarios in the *"Operational Service Scenarios (C11)"* and the *"Data Needs and Availability Prospectus (C12)"* the needs with respect to the EO infrastructure are derived for the medium (2-5 years) and longer (5-10 years) term:

5.1. EO Space Segment

- Long term continuity of EO satellite missions: The GSE FM services require a long term perspective of EO data provision to justify the adaptation of the users' infrastructure to using EO services. The long term continuity of the EO data as main data source for the GSE services must be guaranteed. GMES is totally depending on the maintenance of EO systems and on their upgrade and/or replacement over time. Follow-on missions and upgrading of sensors have to be planned within long term continuing satellite programs.

- In particular, with relevance to GSE FM, this means that in the period 2004 – 2007 the IRS-1C/D satellites will be replaced or supplemented by the IRS P5 / P6 missions. Moreover, until the end of 2007 it is assumed that Landsat 7 will be replaced by the follow-on Landsat Data Continuity Mission (LDCM), and ENVISAT ASAR will be supplemented by TerraSAR-X. For the period 2007 – 2012 this means that at least two new missions with optical and/or SAR sensors (and with a geometric resolution relevant for GSE FM) will be available, e.g. the Pleiades System and COSMO SkyMed. Moreover, additional missions are most likely to be available, e.g. ALOS, Radarsat-2, RapidEye.

- Lack of timeliness and insufficient frequency of EO observations with optical sensors: The critical problem for optical data is the availability of cloud-free data over a certain region at a defined time period. Due to cloud coverage, it is necessary to have a more frequent coverage with EO data by increasing the revisit frequency. This could be done by either (a) a satellite configuration with several identical satellites on the same orbit or (b) a satellite configuration which integrates several satellites into a harmonised system and/or (c) satellites with high spatial resolution and much higher swath width to increase revisit time considerably.

- Redundancy and backup capability of EO missions: The current severe problems with Landsat 7 clearly show the urgent requirement that EO missions need redundancy and backup capabilities. For operational service provision it must be ensured that in case of technical problems with a single satellite or even the loss of satellites this data gap can be compensated without any time delay.

5.2. EO Ground Segment

- Adaptation of the existing EO ground segment to the new or follow-on missions, which are relevant for GSE FM. This includes investments for the data acquisition, processing and archiving infrastructure.

- It is assumed that during the period 2-5 years the European EO ground segment has to be upgraded and extended for at least (minimum) 2 new EO missions. For the 5-10 years period it is assumed that an upgrade with respect to at least 3 (minimum) additional missions is needed. Moreover, it is assumed, that in the 5-10 years period it might be necessary to establish 1 new EO ground station in a non-European location.

- The acquisition capacity of the EO ground segment is either sufficient or can be upgraded. E.g. the total number of Landsat 7 scenes received at the 4 ESA station was about 17.200 scenes in the year 2002 (see “*Precursor systems Inventory S9”* document).

- There is a strong demand for a European “Integrated Ground Segment”. The European data acquisition is not harmonised; for each satellite system different organisations are responsible. Thus, the data acquisition policies are ruled by quite heterogeneous goals. A harmonised data supply is desirable from the viewpoint of the GSE service portfolio.

5.3. Further Issues

- Long-term continuity also requires the setting up of institutional and commercial funding mechanisms, which means that the funding for these operational systems has to be shifted from the research and development domain to budget lines in the institutional or commercial funding framework.

- European EO capacities: To compensate the current problems with Landsat 7 as soon as possible it is necessary that Europe either builds own capacities of multi-spectral imagery at a Landsat compatible geometric and spectral resolution (“European Landsat“) and/or closely cooperates with U.S. agencies NASA and USGS for the implementation of the Landsat Continuity Mission.

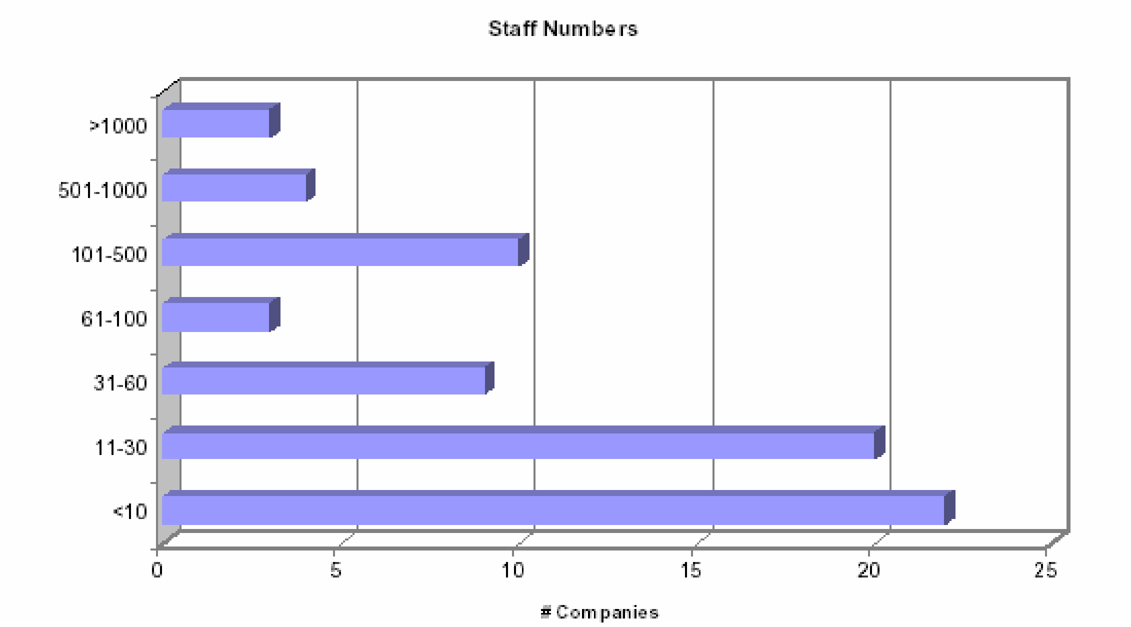
6. Growth Paths for Service Infrastructure

6.1. Situation of the EO Service Infrastructure

In forestry, the use of satellite imagery has a long tradition. Currently, many small companies offering mapping and monitoring services exist world-wide. According to a study initiated by the Centre for Earth Observation (CEO, 1996) about 85 % of all European enterprises in remote sensing have less than 20 employees. Only 3 companies in Europe have more than 50 employees. But these are companies, which are funded partly or in total by governments.

According to a recent study carried out under the framework of ESA EOMD projects this situation has not changed at all (see Fig. 2).

Fig. 2: Company size of EO service industry (Curtis & Knops, 2003)



The majority of companies are small, almost 60% of respondents have less than 30 people (Curtis & Knops (2003): Market Development Survey - Preliminary Findings. VEGA & Booz Allen Hamilton; EO Services Industry Consolidation Workshop; November 5, 2003). In their study VEGA & Booz Allen Hamilton characterize the current EO service industry as:

- Small
- Highly technically qualified staff
- Following market requirements rather than making them
- Constrained by sales effectiveness

- lack of resources
- small companies remote from global client base
- use of agents
- competition to displace traditional methods

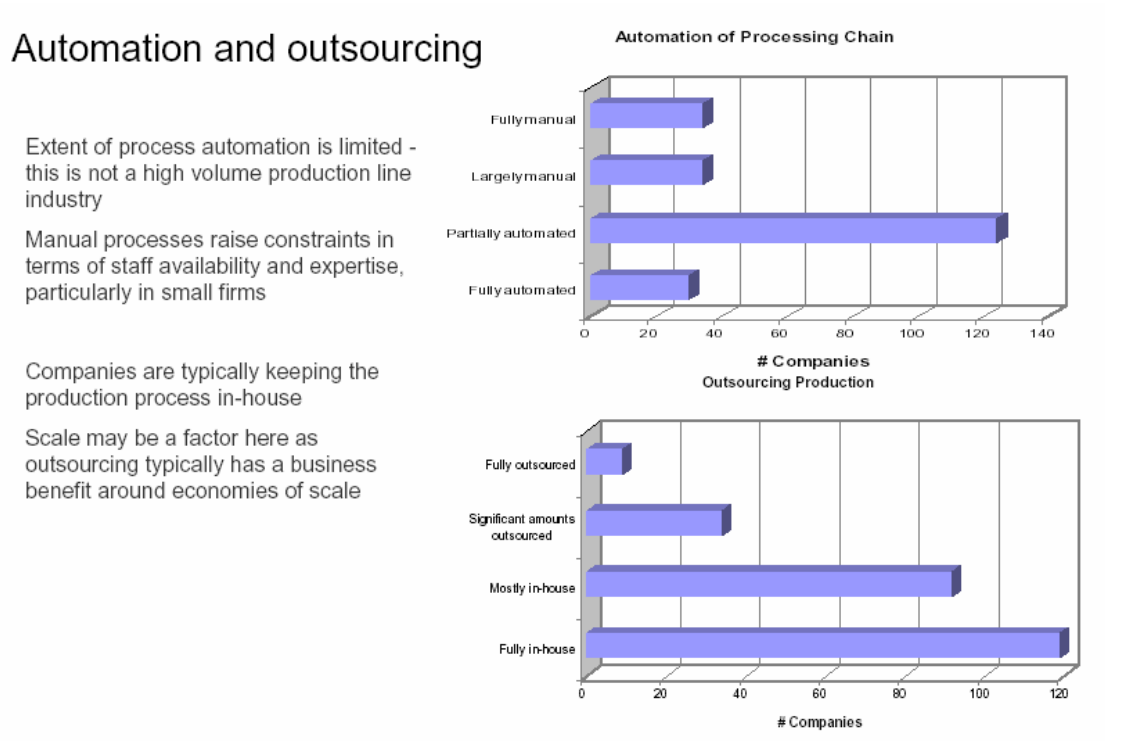
Hence, most service providers have no possibilities to offer products that could induce market growth, so that their business opportunities are very limited due to a stagnating market.

Nevertheless, there is a strong movement towards vertical integration of small value-adding companies. In addition one can observe increasing mergers and acquisitions showing an industry-wide desire to bring more capabilities in-house. Interesting enough, many of these capabilities are outside the traditional definitions of remote sensing and GIS (Frost & Sullivan, 2003).

However, the EO service industry world-wide is still fragmented and fragile, and in some respect ineffective. This goes in line with limited evidence of mature and repeatable products in the face of immature requirements from industry and institutional markets.

Most value adding companies have expert skills but a strong regional focus. They usually have only few automated processes and are very dependent on satellite data providers, i.e. availability of EO data (Fig. 3).

Fig. 3: Level of automation and outsourcing in the EO service industry (Curtis & Knops, 2003)



A good overview of the current service provider scene can be obtained from the EO Portal (http://directory.eoportal.org/res_p1_Forestandnaturalvegetation.html), where currently (August 2004) 366 organisations are listed as consultants or service providers under the key word “Forest & natural vegetation”.

6.2. Necessary Infrastructure and Data Sources

The following chapter compares the capacities and performances of the existing Service Infrastructure Elements to the requirements of the Operational Scenarios for the 2-5 years and 5-10 years horizons described in C11 V2. The analysis will focus on the effective mapping areas per year for 2005 (short-term), 2008 (mid-term) and 2012 (long-term) (ref. C11 V2, table 19).

The Service Infrastructure elements identified and used for the service provision at present will have to be scaled-up. The Service Infrastructure Inventory (S9) showed that:

- Scaling-up of technical infrastructure is not limited. Most of the Service Infrastructure elements are based on standard hardware and COTS which are easy to scale up. Capacities of IT-infrastructure (storage media, computers with high performance) seem to be assured.
- Scaling-up of Service Infrastructure elements to an European/global dimension is currently restricted by:
    1. The availability of trained interpretation staff with specific regional/local knowledge.
    2. The availability of auxiliary data, especially of topographic maps (in most cases: high dependency stated).

6.3. Capacities and Performance

Tab. 5 to 7 compare the approximated capacities needed for service production in short-term, mid-term and long-term perspective based on the Operational Service Scenario C11 V2. (considering table 19, effective mapping area per year)

Tab. 5: Capacities needed for service provision - 2005

Service Package	**Capacity needed [km²/year]**	**Service Infrastructure element**	**Capacity available [km²/year]**	**Comment** (overcapacity: ➚; under-capacity: ➘)
Nat. GHG	270,000	Land Use Clutter Mapping	840,000	➚
Nat. GHG	270,000	Forest Cover Map using SAR data	~360,000	➚
Nat GHG	270,000	Land use Mapping Geoapikonisis	~360,000	➚
CDM	30,000	Land Cover for CDM	~ 600,000	➚
Disturb.	270,000	Forest Control System Sweden	~365 scenes (landsat: 360,000, SPOT: 30,000)	➚
Sub-nat.	20,000	Sub national Forest GIS Update	~32,000	➚
LC&FI	260,000	Land Use Clutter Mapping	840,000	➚

Tab. 6: Capacities needed for service provision - 2008

Service Package	**Capacity needed [km²/year]**	**Service Infrastructure element**	**Capacity available [km²/year]**	**Comment** (overcapacity: ➚; under-capacity: ➘)
Nat. GHG	750,000	Land Use Clutter Mapping	840,000	➚
Nat. GHG	750,000	Forest Cover Map using SAR data	~360,000	➘
Nat GHG	750,000	Land use Mapping Geoapikonisis	~360,000	➘
CDM	70,000	Land Cover for CDM	~ 600,000	➚
Disturb.	910,000	Forest Control System Sweden	~365 scenes (Landsat: 360,000, SPOT: 30,000)	➘
Sub-nat.	150,000	Sub national Forest GIS Update	~32,000	➘
LC&FI	840,000	Land Use Clutter Mapping	840,000	➔

Tab. 7: Capacities needed for service provision - 2012

Service Package	**Capacity needed [km²/year]**	**Service Infrastructure element**	**Capacity available [km²/year]**	**Comment** (overcapacity: ➚; under-capacity: ➘)
Nat. GHG	1,600,000	Land Use Clutter Mapping	840,000	➘
Nat. GHG	1,600,000	Forest Cover Map using SAR data	~360,000	➘
Nat GHG	1,600,000	Land use Mapping Geoapikonisis	~360,000	➘
CDM	130,000	Land Cover for CDM	~ 600,000	➚
Disturb.	1,500,000	Forest Control System Sweden	~365 scenes (landsat: 360,000, SPOT: 30,000)	➘
Sub-nat.	590,000	Sub national Forest GIS Update	~32,000	➘
LC&FI	1,900,000	Land Use Clutter Mapping	840,000	➘

With respect to the short-term horizon (2005) the existing service infrastructure elements are sufficient to provide the required capacities. Upgrades of existing elements will be necessary in mid-term and long-term perspective. Upgrading these elements could be twofold:

(1) Setting up networks of service infrastructure elements. For example, the capacities needed for National GHG reporting in 2012 could be fulfilled by setting-up joint & networked production capacities of existing service providers.

(2) Extension and optimisation of Service Infrastructure elements, e.g.:

- Improvement of processing chains
- Improvement of automated production steps
- Standardization of work-flows
- Optimisation of data procurement and data-flows
- Improvement of QA measures

6.4. Necessary Upgrades and New Elements

Service Infrastructure elements which need to be upgraded or replaced and improvements identified are:

- **Land Use Clutter Mapping**:
    - Improve automated production steps, reduce manual work parts (e.g. "Computer assisted refinement of work layers: 80% manual work) by optimizing process chain
    - Build-up/increase resources: e.g.: ~20 times more staff needed to meet capacity considered in scenario 5-10 years, best case.
    - Supplement existing capacities with relevant Service Infrastructure elements of additional European service providers (e.g. general land cover from GSE Land team).
- **Sub National Forest GIS Update**:
    - Improve processing chain; Generation of Forest Mask is only partly operational.
    - Build-up/increase resources: e.g.: ~1.4 times more staff needed to meet capacity considered in scenario 5-10 years, best case. Main blockages: timely availability of well educated interpretation staff

  - Supplement existing capacities with relevant Service Infrastructure elements of additional European service providers (e.g. to carry out multi-phase / multi-stage inventories with an optimised terrestrial phase)

- **Land Use Mapping Geoapikonisis**:

  - Improve automated production steps, reduce manual work parts (e.g. “Computer assisted refinement of work layers: 100% manual work!) by optimizing process chain

  - Build-up/increase resources: e.g.: ~1.4 times more staff needed to meet capacity considered in scenario 5-10 years, best case. Main blockages: timely availability of well educated interpretation staff

  - Supplement existing capacities with relevant Service Infrastructure elements of additional European service providers.

- **Forest Control System Sweden**:

  - Improve automated production steps, reduce manual work parts (e.g. “Clear Cut Monitoring: 80% manual work) by optimizing process chain

  - Build-up/increase resources: e.g.: using Landsat-data: ~1.8 times more staff needed to meet capacity considered in scenario 5-10 years, best case; using Spot-data: ~21 times more staff needed!

  - Use of Landsat-data instead of Spot-data; Main blockages: Availability of yearly coverage with cloud free satellite data.

  - Supplement existing capacities with relevant Service Infrastructure elements of additional European service providers.

- **Irkutsk Regional Forest Monitoring System**:

  - Improve GIS Based Inventory Data

  - Establish regional medium resolution EO data receiving capacity. Build-up/increase resources for using MODIS-type and Landsat-type data

  - Use of Landsat-type data instead of Aerial Photography for far regions forest inventory. Many far regions are not under human control and medium resolution inventory and/or changes monitoring is better than the detail inventory of 10-15 years old.

  - Supplement existing capacities with relevant Service Infrastructure elements.

6.5. Model and Ancillary Data Sources

One of the basic assumptions for the operational service scenarios in the time frame of 2-5 years, as well as 5-10 years is the availability of data sources needed for the service provision. Service provision will be extended to a geographical coverage comprising EU member states and New Accession States (NAS) (most dynamically in 2-5 years horizon) as well as areas outside EU and NAS (see C11). In these cases, the existing model and ancillary data sources will not be able to ensure the service provision (see C12 - Data needs and availability prospectus for further details):

- Availability of DEMs: not very critical due to large coverage (SRTM, Mona Pro) and low update-rate needed. High resolution DEMs critical

- Availability of topographic maps: in EU member states and most of the NAS not critical; potentially critical in other regions (Africa, Asia, S-America); update-status of existing topographical maps varies.

- Availability of land use maps: coverage in EU member states not critical; CLC 2000 can be used, but access conditions have to be clarified; update-status wrt 5-10 years horizon might be critical due to 10-years update cycle of CORINE. The coverage of land use maps outside EU is a critical issue due to heterogeneous or missing data sources.

- Availability of forest cover maps and forest inventories: most critical issue due to limitations of coverage to specific areas and regions and the missing standards of mapping approaches, thematic content, scale, accuracy and update-status.

To ensure the availability of data sources needed for service provision in the future, the following improvements and upgrades will be necessary:

- Ensure availability of standardized and accessible DEMs with European and global coverage as a basic input data source for service provision.

- Improve availability of topographic maps or comparable data sources, especially outside Europe.

- Ensure availability of standardized and accessible land use data sources; improvement of CORINE approach needed with respect to coverage, thematic resolution and update-cycle.

- Improve coverage of forest cover maps and forest inventories; foster standardization and harmonization of mapping.

- Investigate the possibility to provide basic ancillary information from internal sources (i.e. own dedicated inventories), in order to achieve more independence from existing data sources such as public survey institutes.

7. Growth Paths for User and In-Situ Infrastructure

7.1. Necessary Infrastructure and Data Sources

To ensure further growth, it will be necessary that the infrastructure of end-user-organisations will be able to handle the GSE Forest Monitoring products and to integrate the products in the users' working environment. It is expected that the penetration of broadband Internet access will increase in the whole European area. This will allow better interactivity with the end users. This would also enhance possibilities for bi-directional web-based data exchange.

Requirements towards necessary infrastructure and data sources will in the longer term evolve in parallel with technological capacity of (among other but mainly) Earth Observation sources. Higher resolution coverage, increase of temporal resolution will put higher demands to the user infrastructure.

GIS infrastructure may need capacity building in countries in the African and Western Asia regions as identified in chapter 4.3.1.

It is not foreseen that there will be a change in the provision of input data sources. For the Forest Environmental Indicators, the continuation of the monitoring scheme under ICP Forests and Forest Focus needs to be ensured (the effectiveness of the scheme will be reviewed in 2005 in order to provide a basis for any decisions on the continuation of these activities after 2006.). Additional data as topographic maps, digital elevation models and land use maps need to be available and up-to-date.

7.2. Capacities and Performance

It is not foreseen that there will be over-capacity of infrastructure elements. A likely option is that different national and supra-national (EU) monitoring schemes will show increased degree of convergence in 5 to 10 years time.

7.3. Necessary Upgrades and New Elements

Faster desktop computers would allow increased penetration of the GSE Forest Monitoring data and services and would increase the user base and support. E.g. High-resolution maps would become available to the public at large, with the option to analyze the content on the fly.

8. Recommendations for the GSE Implementation Phase

With its extensive reliance on EO data sources as the basis for products and services, the future of GSE-FM depends upon the availability and reliability of a large and inter-related technical infrastructure that includes space based systems down to data processing capabilities at the service provider and infrastructure at the users' level. Clearly, the future growth of many of these technical components is beyond the influence of specific action items that may be financed and implemented under the GSE-FM project.

The following recommendations can be given with respect to the implementation of the GSE FM services.

8.1. Space Infrastructure

General recommendations:

- The continuation and operational availability of EO satellites with optical sensors and SAR sensors must be ensured. A long-term plan for operational Earth Observation should be established, which will outline the need for the replacement of satellites. The realization of the envisaged super-spectral imaging family (Landsat data type continuity) as ESA sentinel mission is essential for the GSE FM services.

- Sufficient frequency and timeliness of observations and data must be ensured. According to the enlargement scenario of the GSE-FM services the EO data will be needed more frequently and for larger areas.

- The archives with historical EO data from optical and SAR data must be guaranteed available and accessible. Reliable access and long-term data storage in the archives must be ensured.

- The European EO ground infrastructure must be fully operational as an "Integrated ground segment" harmonised between the main world-wide space agencies especially if GSE-FM is to have a global coverage and user base. The infrastructure will support a complex constellation of satellites in orbit. The data distribution mechanism should be common to all missions (including processing and archiving) and feed required data into the GSE-FM user and service provider network.

Based on the results of the 3rd co-location meeting and discussions with other consortia, there is a strong need to extend the current role of the ground segments in order to enhance the productivity and relieve the present burden on service providers by extending the current capabilities of the European EO ground segments. For instance, DLR is prepared to provide this service in cooperation with other facilities in Europe as horizontal support activity for several GSE's. These extended ground facilities (Tab. 8) provide among others the following tasks:

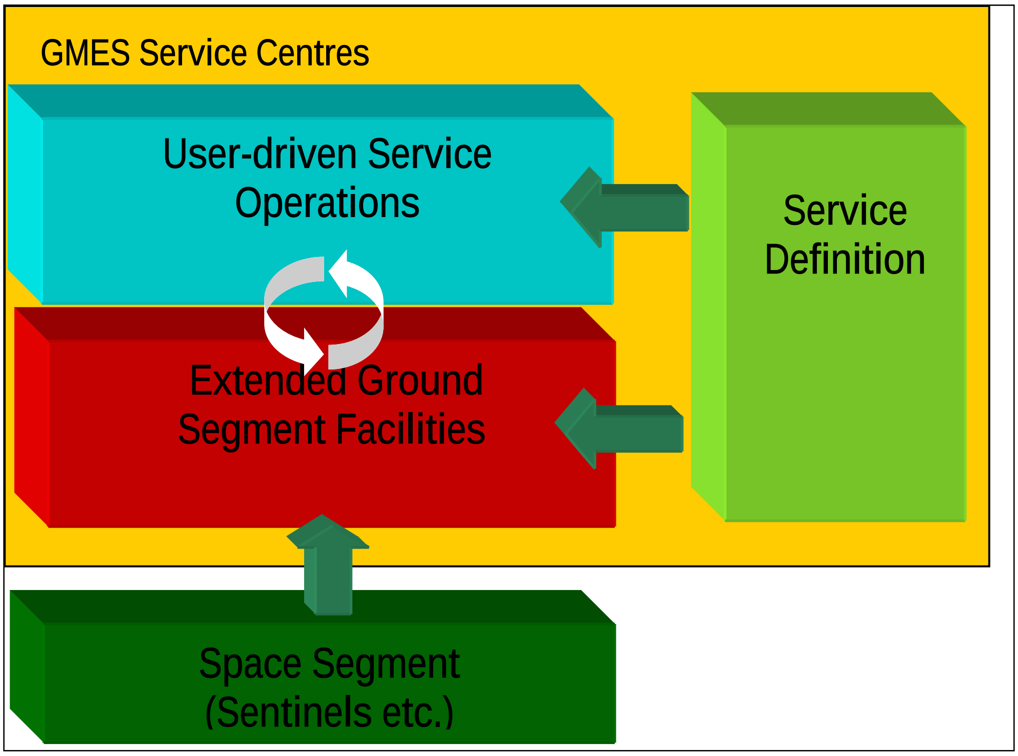
- Generating baseline products by *standardized geometric and radiometric pre-processing*. This includes ortho-correction as well as radiometric calibration and atmospheric correction in a highly standardized and transferable manner. A similar approach has been successfully used in the CLC2000 / Image 2000 project and should therefore be extended to further European pre-processing capabilities.

- Generating and providing *commonly accessible data pools*, which are used by several GSE services. For all land related service this is especially needed for Digital Elevation Models (DEM). The generation and consistent archiving of a European or global DEM with high resolution as a horizontal activity for several GSE services would considerably improve the quality and homogeneity of the GSE products.

- Generating *basic value-adding products*, e.g. generic land cover and land cover change products according to or similar to the CLC nomenclature.

- Establishing interfaces and links to the non-EO components needed for GSE services, e.g. the INSPIRE initiative for the European spatial data infrastructure or other relevant user and in-situ data bases.

Tab. 8: GSE Service Centres including extended ground segment facilities



8.2. Service Infrastructure

- The processing capacities of the service providers have to be adapted to generate the GSE-FM services more effectively as user demands increase over time. This has to include more efficient production chains and – possibly – the adaptation of COTS software image processing and GIS systems towards higher throughput.

- The designated service providers must ensure that the product and service generation chains are robust and flexible. The production process must be flexible enough to enable e.g. the replacement of input data sources. This is an ongoing system requirement which requires monitoring and enhancement.

- To fulfil requirements on capacities in a mid- and long-term horizon, production networks have to be set-up. This networking shall rely on standardized processes and interfaces to assure quality of products and effectiveness of work-flows. This requires a sound technical interface management.

- Interfaces to data providers should be set-up or improved on technical and commercial level to ensure access to models and ancillary data sources. Preferably, mid-/long-term access agreements with data providers should be achieved.

- In case that no data providers for model data can be found for a specific area, production capabilities should be enhanced towards the autonomous production of such “ancillary data”. This is especially true for areas out of Europe. Without such information it is not possible to produce the complete product suite, especially in higher scales. Thus, it is recommended to investigate the possibility to provide such basic ancillary information from other sources, in order to achieve more independency from existing data sources such as public survey institutes. For that two possibilities exist:

  1. to produce all data by upgrading own capacities (e.g. by integration of field survey or airborne data within multi-phase / multi-stage inventory concepts).

  2. ancillary data may be procured from external sources such as specialised service providers (e.g. general land cover from GSE Land team). Although this would increase the production cost it will assure that even in case of current unavailability of model and ancillary data from public sources delivery of services is possible, world-wide.

8.3. User and In-situ Infrastructure

- The infrastructure of the new user sites will have to be adapted and upgraded to handle the GSE-FM products and to integrate the products into the users working environment. Guidelines will have to be developed to facilitate this process world-wide and in different technical environments.

- The required in-situ data and National Forest Inventories (NFI) data have to be accessible to and be made available by the users to GSE Forest Monitoring.

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