

USER REQUIREMENTS STUDY

**FOR
REMOTE SENSING BASED SPATIAL INFORMATION
FOR
THE SUSTAINABLE MANAGEMENT OF FORESTS**

WORKPACKAGE REPORT

[Workpackages 5 & 7]

USER REQUIREMENTS VERSUS EXISTING CAPABILITIES



November 1998

ITC In cooperation with
IBN-DLO
Fokker Space BV

FAO
WAU
NLR

IKC N
DOFI
TNO-FEL

NIVR
NEO
Vissers DataManagement

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Preface

This study originates from the problems observed with information availability for sustainable forest management. It aims at addressing the following issues:

1. Identification of users of spatial information for forest management
2. Assessment of the information needs
3. Translation of these needs into functional and system requirements
4. Identification and assessment of existing and planned technology for application in forest management
5. Assessment of the extent to which information requirements are and/or can be met by existing/planned technology
6. Preliminary assessment of the need for an “end-to-end” monitoring system
7. Creation of a national and international platform to support the study

Three Netherlands Ministries have sponsored the study, i.e. the Ministry for Economic Affairs, the Ministry of Foreign Affairs (Netherlands Development Assistance – Neda), and the Ministry of Agriculture, Nature Management and Fisheries.

The study has been carried out by the International Institute for Aerospace Survey and Earth Sciences (ITC) of Enschede, the Netherlands in cooperation with:

- Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy
- National Reference Centre for Nature Management (IKC N), Wageningen, the Netherlands
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- Fokker Space BV, Leiden, the Netherlands
- TNO-Physics and Electronics Laboratory (TNO-FEL), The Hague, the Netherlands
- Vissers DataManagement, Wageningen, the Netherlands

The study results have been laid down in the following reports:

Final Report User Requirements Study

Workpackage Reports

1. International user platform
2. Study approach user needs
3. Forest functions, management principles and information systems
4. User needs
5. Country studies
6. Remote sensing applications for forest management
7. User Requirements versus existing capabilities
8. Proceedings of URS Workshop
9. User Requirements Study – Administrative Report

USER REQUIREMENTS STUDY

USER REQUIREMENTS VERSUS EXISTING CAPABILITIES

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1. INTRODUCTION

This report describes the results of two work packages within the FAME-URS study: work package 5, translation of user needs into user requirements, and work package 7, evaluation of requirements versus application solutions. These results refer to number 3, 5 and 6 of the general objectives of the project (ITC 1997), also listed in the preface of this report.

Work packages 4.1 and 4.2 of the FAME-URS project provided a joint report on the user needs for (spatial) information for forest management, as well as a spreadsheet with the analysis of the answers to the questionnaire. For each user need the spreadsheet shows the percentage of the respondents that expressed this need. The literature study in the report of work package 2 and the five country studies described in the report of work package 4.3 gave depth and color to the information needs of forest managers.

This report of work packages 5 and 7 describes how these user needs were translated into user requirements. The user needs are expressed in "forest management terms", while the user requirements are written in "technical terms". The logical links between the user needs and the different types of requirements were maintained, so it remains clear which requirement originated from which user need. From these long list of requirements those were selected that would be crucial in deciding whether a certain process or technology would provide a viable solution.

Work package 6 of the project supplied documentation on the characteristics of existing sensors and on the forest parameters that could be measured with these sensors. In addition different solutions for receiving stations for satellite data were described. These results were compared with the key system requirements to see which part of the requirements can be satisfied with the existing techniques and to identify gaps in information provision.

2. APPROACH

A "user need" is a need for the supply of data or information on a certain topic. This includes the way in which the data is delivered, speed, frequency of delivery, reliability, and processing the data to produce the required information. A "user requirement" is specified as a demand to a system. This system is not merely a computer, satellite or other piece of hardware. In this document, "system" refers to the whole chain from collecting the primary data till the delivery of the information that is used by the forest manager to plan and decide. It is therefore also called an *end-to-end* system. Of course this system could include remote sensing and automated processing.

We observed the following rules in the formulation of the user requirements:

All requirements are stated in a standard manner of "The system *shall*".

This provides a consistency of expression and gives the same relative importance to all requirements.

1. Of importance is the wording used in specifying a requirement, particularly the verb. The aim is to be specific (such as "The system shall provide...") rather than general (such as "The system shall support..."). However, in some cases the user need is expressed in such general terms that it is not possible to formulate specific requirements.
2. The requirements shall not include any element of a design or a solution.

Three categories of user requirements are relevant for this study:

- Premises, restrictions, guidelines (the context in which the system has to operate)

- Functional requirements (what the system has to do or deliver and how)
- Performance requirements (how well the system should perform its task)

In each of these categories, a number of specific topics can be listed. For each requirement category and each topic within the category, we looked whether one or more of the user needs gave a basis for formulation of a requirement. For some topics, it was difficult or impossible to describe a requirement based on the user needs. In this case, the team tried to formulate requirements based on literature and our own experience and understanding of the users. This is called an indirectly derived requirement.

From the user requirements the key system requirements have been formulated. These are the requirements that should be met by the end-to-end system to satisfy at least a large part of the user needs. These key system requirements usually contain a criterion, for example: classification woody / non-woody vegetation should have at least 90% accuracy.

3. USER REQUIREMENTS

For each category, the most important user requirements will be discussed below. "Important" in this case means, that the need in which the requirement originated was expressed by a substantial percentage of the people who responded to the questionnaire. Annex 1 lists all requirements per category.

3.1. Premises, restrictions, guidelines

Many users require the system to provide data for maps and GIS, store and integrate field data and to acquire and process remotely sensed images, including high resolution images such as aerial photographs. A requirement for time-series was expressed by almost 20% of the users. Because of users' remarks on difficulties in the exchange of data, we added the indirectly derived requirement that the system shall also allow easy linkage with other systems.

The respondents to the questionnaire did not comment on the life cycle of the information supply. We decided to put the requirement for the operational life of the system at 15 to 25 years. Often, implementation of information systems encounters serious difficulties when it entails changes in the structure of the organisation as a whole and in its working methods (Arnbak, 1988, Arnbak *et al.*, 1990, Bates, 1988, Carey, 1989). However, some changes will be inevitable, especially at the level of the work of individuals. Therefore, an indirectly derived requirement states that changes in the organisation and its methods should be limited.

Based on the answers to the questionnaire, information should be made available to all users. Many users reported difficulties in the exchange of data and the acquisition of remotely sensed images. They did not get the data in time or even did not get anything at all. Sometimes this was due to conflicts between countries, sometimes to miscommunication or unwillingness between organisations within the same country. Therefore, indirectly derived requirements are that the system shall be as autonomous as possible, at least for data acquisition and processing, and that it shall allow several levels of restrictions at national level with respect to input data and services. Related to these issues is the indirectly derived requirement for solid arrangements with respect to copyright and right for use of data. Restrictions on use of data might be in conflict with the requirement to make data available to all users.

The software investment for the system shall be low. The system life cycle costs shall be kept low as well, to be able to provide data at low cost. The requirement for cheap hardware was mentioned by less than ten percent of the users. Training and education shall be offered to the users to enable them to operate the system, interpret the data and use this as a base for decisions. For a more precise formulation of the requirements for training and education, further consultation with the users will be necessary. The system should be user-friendly, which we understand as that it should require minimal skills to operate.

The external circumstances are an important element for system design. The report on the country studies says that, at local level, temperature controlled offices, reliable electrical power and telecommunications are often not manageable by local institutions. Depending on the design of the system, certain components of the system may have to function in demanding circumstances. The system should be able to withstand these circumstances.

3.2. Functional requirements

The functional requirements include the acquisition or collection, handling, storage and presentation of spatial data and information on the following themes:

- land cover and forest cover (especially forest-non forest)
- forest types
- changes in the forest, such as changes in area, forest degradation, restoration and regeneration
- topography
- land use,

- distribution of plant and animal species and bio-diversity
- terrain morphology, such as slopes and elevations
- hydrology
- soil type
- forest productivity (both timber and non-timber forest products)
- forest health
- forest fires

The system shall also be capable of acquiring, handling, storing and presenting remotely sensed data, including high-resolution images such as aerial photographs, as well as time series. The system shall acquire, handle, store and present the information in such a way that maps can be produced and that the information can be used as input in a GIS.

In response to the questionnaire, one group of users indicated that they need (more) information on land cover, land use, forest cover and vegetation or forest types at scales 1:10,000 every 5-10 years. Another group needed this information every 1-5 years on scales 1:25,000 or 1:50,000. This implies that the system should be able to acquire, handle, store, process and present this type of forest information at scale 1:10,000 every 5 years and at scales 1:25,000 and 1:50,000 every year.

For information on forest production and stand parameters, the system should acquire, handle, store, process and present this information at scales 1:5,000 and 1:10,000 every year. For forest protection and fire damage assessment the system should acquire, handle, store, process and present the information every 1-3 months.

The scales 1:10,000, 1:25,000 and 1:50,000 coincide with image resolutions between 5, 10 and 20 m, respectively, according to generally accepted topographical standards. For each requirement regarding update frequency of the data, the system should be designed for a double number of information cycles, to have a backup in case of failure. The users indicated they wanted the information presented mainly in the form of maps, so the system should be able to generate maps of the required information at the desired scales.

3.3. Performance requirements

The requirements regarding data age ("up-to-dateness") were based on the frequency requirements, as very few respondents specified the maximum age of the information they were using. The age was set at half the frequency with a maximum of one year. So, in the case of a yearly update, the acquisition, processing and distribution of the data should not take more than six months. If only the desired maximum age was specified, than the frequency was set equal to the maximum age. So, if a map had to be one year old at the most, the frequency was set at once a year. One can imagine that the age requirement also depends on the type of users. Those involved in operational forest management will have higher requirements for recent data than scientific users, especially where illegal logging and forest fires are concerned.

The respondents indicated that access to data is a major problem. They could not acquire remotely sensed data or could not gain access to existing information in other organisations. This implies that an end-to-end system should reach the desk of the user, giving autonomy in data acquisition and processing.

4. SYSTEM REQUIREMENTS

Those user requirements were selected, that would determine whether the system would satisfy at least a large part of the user needs. These requirements were formulated as key system requirements (see Table 4.1). In the formulation of these key system requirements it was also indicated how well the system should perform, e.g. that classification accuracy for woody versus non-woody vegetation should be better than 90%. For the classification of forest cover the FAO approach was adopted. At level 1 the vegetation is split into woody and non-woody vegetation and at level 2 the woody vegetation is split into forest and shrubland. This two-level forest cover classification is one of the key functional system requirements to satisfy the user requirements for forest cover classification.

When forest cover classification is possible with sufficient accuracy, information on changes in forest area, deforestation, fragmentation and reforestation can also be supplied. Furthermore, users need information on forest types. However, it is not clear which forest types they wish to distinguish and with which accuracy. Are these forest types floristic types, structural types or forest use types?

As land use is very much related to land cover, we did not put this in as a separate requirement. We assumed that topographical information usually is supplied by other organisations in a country, and therefore the system does not have to acquire and supply this information.

Table 4.1: Key system requirements for the FAME-URS study

**: the first, smallest figure fore resolution indicates the resolution related to the scale according to the generally accepted topographical standards. The second, larger figure indicates the resolution as sometimes is used in mapping when more detailed data are not available.*

Functional requirements	
Classification (level 1)	Woody / non-woody vegetation; accuracy $\geq 90\%$
Classification (level 2)	Forest / shrubland; accuracy $\geq 80\%$
Map generation	Random location error ≤ 1 pixel
Time series	Stability systematic location error < 1 pixel
Area of interest	10 000 - 1 000 000 km ²
Image resolution	Scale 1: 25 000; resolution 5-10 m *
Image resolution	Scale 1: 50 000; resolution 10-20 m *
Performance requirements	
Coverage (frequency)	0.5 years
Operability	Minimal number of operator actions (automation)
Communicativity	World-wide quick exchange of data (e.g. Internet)
User friendliness	Easily serviceable (e.g. PC-based system, well-known system parts)
Premises, restrictions, guidelines	
Life cycle (service)	15-25 years
Autonomy	Direct satellite-ground link, distributed processing, PC-based (serviceability)
Affordability	Low-cost front-end, low operation costs for the (end-) user
Availability	Area of interest 100% covered
Training/education	Training programs
Impact on organisation and working methods	As minimal as possible
Environmental	Withstand harsh environments, e.g. humid tropics

5. EVALUATION OF EXISTING SOLUTIONS

For the evaluation of the requirements versus existing solutions, we will look at the major components of the end-to-end system: data acquisition; data reception and distribution; and processing of data and the use of the information.

5.1. Data acquisition

To reach as many users as possible, the system should operate world-wide, covering all forested areas. For a world-wide coverage, data acquisition by airborne remote sensing or field survey alone would be too labour-intensive, time consuming and hence costly because of the large area, the difficulties in accessibility and the desired frequent update of data. It has to be kept in mind, however, that for individual countries, on a national or local level airborne sensors might play an important role, because of their higher spatial resolution and more advanced sensors not yet available on satellites. Such advanced airborne sensors are for example high resolution, hyperspectral sensors and multi-band, multi-polarization radar sensors. If world-wide coverage is required, this implies that data acquisition should be carried out using space-borne remote sensing (combined with ground verification). Therefore, only space-borne sensors were considered for the data acquisition segment of the system.

NOAA-AVHRR is not suitable, because the spatial resolution is too low and classification of woody/non-woody and forest/shrubland is not possible. EOS-AM will only be able to cater for those users that are satisfied with a spatial resolution of 10-20 meters (map scales smaller than 1:50,000), i.e. for about one third of the respondents to the questionnaire.

Cloud cover hampers all optical satellite sensors. Frequent passes of the satellite over the same area (e.g. NOAA-AVHRR) increase the probability of obtaining a cloud-free image, or give the possibility of mosaicing images to obtain a cloud-free image. However, the first solution (frequent revisit) goes at the expense of the spatial resolution and the second increases the costs for data acquisition considerably. But even then, some areas will never be cloud-free, so a 100% global forest cover is not possible.

Cloud cover does not hamper radar remote sensing. However, the existing radar sensors on RADARSAT 1 and 2, ERS-2, ENVISAT (planned) and JERS-1 (just shut down) do not give satisfactory classification accuracy for forest cover mapping. This could be overcome by using a radar sensor with another frequency and polarisation, as experience with airborne radar sensors has shown.

5.2. Data reception and distribution

The respondents indicated that access to data and information is a major problem. They could not acquire remotely sensed data or could not access to existing information in other organisations. This implies that an end-to-end system should reach the desk of the user, giving autonomy in data acquisition and processing. The acquisition of satellite images in a number of areas is hampered by the absence of receiving stations. For satellites that have no on-board tape recorder, this means that a satellite cannot acquire and transmit an image of an area when the satellite is not within the field of view of a receiving station.

Furthermore, political and communication issues can prevent users from acquiring images from a receiving station, even if the images have been recorded and downloaded. This could be overcome by increasing the number of receiving stations, including local receiving stations for individual organisations or groups of organisations. As the system should be low-cost and user-friendly, receiving and processing should be PC-based (available and serviceable all over the world at relatively low cost) and as automated as possible.

Until now, low-cost receiving stations, based on PCs, are only available for receiving NOAA-AVHRR data. These stations cost less than US\$ 25,000. The RAPIDS mobile receiving station is also PC-based and can be used for receiving data from SPOT and ERS satellites. Potentially, other satellites can be added to the

capability. However, this receiving station is more expensive: about US\$ 500,000. For the existing earth observation satellites, fees have to be paid for the data received.

Quick exchange of data and information world-wide was also indicated as very important. This could be achieved by using Internet facilities, as a number of users suggested. FAO provides access to forestry databases via his forestry website. UNEP has its Global Resource Information Database (GRID) website. Several organisations like the World Conservation and Monitoring Centre (WCMC) and IUFRO are also developing world-wide information services based on Internet applications. These initiatives increase the accessibility of existing information. However, as they depend on including information provided and generated by others, they are not able to cover all forested areas with the same level of detail or to update information with the desired frequency.

5.3. Processing of data and the use of the information

Standard image processing software for PCs is widely available. Development of dedicated program modules for automated geo-referencing and mosaicing that could be used with this software would greatly enhance the user-friendliness.

Last but not least, the users indicated a need for training and capacity building, mainly in the field of image interpretation and GIS for forestry applications. It is not clear whether existing courses are not sufficiently available to the users or not sufficiently suited to their needs.

6. DISCUSSION

As has been indicated previously, the present supply of spatial information to the forestry community is not sufficient. There is a need for more and better information. If we look at the process from begin (data acquisition) to end (an information product on the desk of the user), three segments of the chain can be identified, each with their own set of bottlenecks. On a short term, information supply could be improved by addressing the bottlenecks in the existing chain of information supply, while developing a dedicated system for forest information on the longer term. Below the three main segments of the process with their bottlenecks are listed.

6.1. Data acquisition

As indicated earlier, a sensor on a satellite platform would be a suitable tool for data acquisition. Spectral characteristics of the sensor determine whether it can discern certain land cover classes and also whether cloud cover will hamper image acquisition. The spatial resolution determines the level of detail (scale) of the information that can be produced. Whether and how often the area of interest is covered depends mainly on the characteristics of the platform. Many existing platform/sensor combinations are for research and not for operational use. None of the existing platform/sensor combinations completely satisfies the data requirements for meeting the user needs for information on forest cover, forest types, forest production and fire damage assessment. However, part of the needs could be satisfied by better or more widespread use of the existing sensors. On the longer term, development of a dedicated, operational platform/sensor combination for forestry will be a more comprehensive solution.

6.2. Data reception and distribution

For all existing satellite sensors, receiving stations that can download the data do exist. However, existing stations are not covering the whole world for all sensors. Furthermore, the data recorded in receiving stations are not available to all users world-wide, as they may not have access to the existing images or lack the funds to buy them. Pre-processing of raw data still requires considerable operator involvement, and would need automation to become operational. Solutions could be either an increase of the number of receiving stations, or a better access of the users to the data in the receiving stations, which is depending on the availability of financial resources and political will. Local receiving stations for individual organisations or groups of organisations, would increase both the area covered by the receiving stations as well as improve the access of the users to the remotely sensed data. Pre-processing should be further automated.

6.3. Processing of data and use of the information

Existing image processing and GIS software is widely and easily available, as well as the necessary hardware. Organisations need capacity building to make better use of the existing techniques for image interpretation and the use of GIS for their applications. On the short term, training could be given to improve the use of the existing software. On the longer term, dedicated user-friendly software could be developed for certain applications like geo-referencing, map generation and change detection.

Short term solutions address bottlenecks in existing information supply. However, solving a bottleneck in one part of the chain might create a new one further down the chain. Longer-term solutions, for instance developing a dedicated end-to-end system, provide a more integrated and complete solution.

Both short-term and long-term solutions have to be developed in parallel. The short-term trouble shooting builds the communication within the forestry community world-wide and creates the international platform needed for a dedicated system, as well as developing a mutual understanding between the forestry community and the remote sensing community, which will greatly benefit the development of viable long-term solutions. These long-term solutions will safeguard the production of information for sustainable forest management in the coming decades.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

Based on the results of the work packages 5 and 7, described in this report and discussed during the workshop (Rowe and Heering 1999), we came to the following conclusions:

- There is no existing end-to-end system that completely satisfies all system requirements with respect to information on location and extent of the forest, which is the most important type of information as specified by the users.
- Distribution of the remotely sensed data is the weakest part in the chain from data acquisition to delivery of the information at the desk of the user. Main distribution bottlenecks are a lack of access to existing remotely sensed data and/or not enough financial resources to buy the data.
- Existing technical solutions for acquiring data and information on the forests, based on remote sensing, are still not fully operational. The existing solutions are not user friendly, as operation requires a lot of actions (lack of automation) and there is no guaranteed continuity in the supply of data.
- Training and capacity building are needed to enable users to make (better) use of the existing data and information.
- Technically speaking it is possible to acquire more data on the forest using remote sensing than what is possible with existing sensors on board satellites. With the development of new sensors, data and information on more and other themes of the forest could be supplied.
- New sensors are considered as valuable contributions only if above bottlenecks are solved simultaneously.

7.2 Recommendations

Improvement in the supply of data and information on forests to people involved in forest management should adopt a *parallel approach*, consisting of *short term solutions* for the most urgent bottlenecks while in the meantime working to reach *objectives for the longer term*, i.e. contributing to a more sustainable use of the forest through better information supply.

Awareness raising plays a key role in improving the supply of information on forests. Political leaders and the general public should become more aware about the need for more sustainable use of the forests and the role information supply plays in both planning and control of this management. This increased awareness should result in commitment, which can resolve a large part of the bottlenecks encountered in the distribution of existing data, by making existing data accessible and providing sufficient financial resources to acquire data.

Short term solutions could be to improve the distribution of remotely sensed data by installing local receiving stations *and* by negotiating reduced prices for images. Existing data sets should become more accessible. Another short term solution is to make better use of existing data through the development of user friendly automated data processing and providing training to the users of the data.

On the longer term, (a) continuous, operational end-to-end system(s), optimized for forest applications should be developed, including capacity building in the user organizations.

Further research is needed on the limits of the possibilities of existing systems, the possibilities that could be created with new technology and on which these new possibilities are useful for users of information on forest.

The discussion on the specification of the needs for information on the forest, as well as setting priorities in these needs (e.g. the most important information themes), should continue and be part of the parallel process of short term solutions and working towards long term objectives.

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APPENDIX

APPENDIX 1

USER REQUIREMENTS

User requirements, as translated from the user needs. If a requirement is high on the list under a topic, this means that more users expressed the need on which it was based, than when a requirement is lower on the list. One user need can be translated into several user requirements, while the same user requirement can be based upon different user needs.

**: this requirement is an indirectly derived requirement, formulated by the work package 5 team*