The Use of MOMS-2P-Data for Forest Assessments and Updating Forest Management Information in the Rhineland-Palatinate

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Summary

of the final report

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A sustainable use of forest resources (including various aspects such as economic use, environmental and recreational functions) requires detailed, preferably holistic, concepts which all are dependent of precise and up-to-date information. These information needs are served by various types of forest inventories which are carried out in more or less regular time intervals. In addition to time consuming terrain surveys these inventories have been traditionally supported by visual interpretation of aerial photographs; the same data source is also employed for the operational production of forest management maps.

However, the forest management services are confronted with an increasing volume of tasks, including the forthcoming certification of a sustainable timber production. With regard to the limited financial resources it becomes obvious that the role of Information Systems and the use of additional data sources from operational remote sensing satellites, preferably with high spatial resolution, presents valuable alternatives to support the information needs of forest administration and management services.

The project objectives have thus been defined to evaluate the suitability of high spatial resolution spaceborne remote sensing systems for acquiring objective information for assessing forest conditions and updating forest management data bases with regard in the context of specific case studies. While the project was not conceived to completely replace traditional inventory concepts the major emphasis was directed to link existing information data bases with additional and complementary information derived from satellite platforms. Given the technical problems during the acquisition of experimental data from the Priroda spacecraft, the project had to build on supplementary data sources from existing spaceborne systems and airborne sensors (DPA) which are suited to simulate imaging capacities of the MOMS instrument.

1. GIS and Remote Sensing in Forestry Applications

As part of the study the existing situation of using Geoinformation Systems and remote sensing data in the federal state of the Rhineland Palatinate has been analysed. While during the execution of the project the final specification of a dedicated Forest Information System had not yet been accomplished it was an important task to understand whether and, if possible, how a linkage between existing forest data bases and available GIS products can be established. In the frame of a specific case study (Development of an ARC/View-based Forest Information System, forest district of Hillesheim, see also final report, chapter 3-5 and appendix) it could be documented that a transfer of the available vector data base of forest management units can be transferred into ARC/Info and ARC/View without loss of topology information. Also, the available data base of forestry information (Forsteinrichtung) can be integrated and linked to the prototype system. The ARC/View user interface has been adapted to specific needs of forestry management services, such that also not specifically trained staff can operate the system. The integration of up-to-date image information from remote sensing systems also provides a valuable support for preparing and updating forest inventories.

2. Satellite Data Pre-Processing

In order to support the more specific thematic evaluation of remote sensing data by suitable digital image processing options the satellite raw data have to undergo specific pre-processing steps. In particular, these processing steps include high precision geocoding and radiometric correction procedures. These ensure the proper registration of remote sensing data sources

with existing forestry information (GIS data bases) and the conversion of raw digital count values into physical quantities (radiance/reflectance) required for specific interpretation approaches. In the project context, existing pre-processing methods have been optimised and combined with digital terrain models provided by the Topographic Survey of the Rhineland Palatinate (Landesvermessungsamt Rheinland-Pfalz). Based on these methods it is possible to derive ortho-projected image data over morphologically variable terrain which are free of terrain-induced illumination effects (see also final report, chapter 6). These are important requirements for an optimised integration of remote sensing imagery into forest assessment and management tasks.

3. The production of very high resolution mulitspectral datasets employing data fusion techniques

Both currently available and future satellite-based sensors designed for the acquisition of spatial datasets with a very high geometric resolution are co-hosting a panchromatic reference channel characterised by the maximum geometric resolution technically possible, and a number of multispectral channels (which most frequently comprise the visible and near-infrared portions of the electromagnetic spectrum) with a lower geometric resolution (e.g. SPOT, IRS, Landsat-ETM, Ikonos-2). If these kinds of datasets are supposed to benefit to forest assessments or the update of forest inventory databases, it is mandatory to dispose of the multi-spectral information on the highest level of geometric resolution attainable. Consequently, the objective is to develop highly-efficient data-fusion algorithms which are tailored towards "sharpening" low-resolution multi-spectral channels based on the more detailed information inherent in the panchromatic channel.
In the context of this project, a data-fusion approach meeting the requirements set before was developed (local regression analysis, LSM) and evaluated in relation to existing approaches. This evaluation was based on data produced by the Digital Photogrammetry Aperture ("Digitale Photogrammetrie Ausstattung", DPA) - a sensor device which was flown in the frame of the project in the area of the Forstamt Hillesheim (see final report chapter 7.1). Summarising the study it can be noted that compared to ten alternative algorithms, the approach developed by the Remote Sensing Department proved highly competitive and could even be established as the superior solution in many cases. Especially with regards to the radiometric quality of the fused data substantial progress has been achieved, which is of utmost importance in the context of subsequent thematic interpretation steps.
For the future, the availability of such sophisticated data fusion techniques will support the provision of multi-spectral datasets with very high geometric resolution (up to 1x1 m^2 pixel size), which equal the suitability of colour infrared aerial images for a wide range of applications, while even being superior for specific purposes. Hence, the annual campaigns for the acquisition of aerial photographs might be partially substituted by the utilisation of high-resolution satellite imagery, the decision now being exclusively determined by economical considerations.

4. Assessment and analysis of insect calamities

Beside the widespread problem of forest decline, the spatially differentiated and timely assessment of insect calamities is an important element in the inventory of forest resources. With the growing availability of a range of satellite sensors, the potential of assessing damages caused by insects with only little delay has been increasing, suggesting to evaluate in how far data from spaceborne sensors can complement or even be an alternative for

traditional airborne sensors. In the context of the project this was evaluated through a case study analysing a gypsy-moth infestation in the "Bienwald", a forest area in the south of Rhineland-Palatinate. This study was accompanied by a detailed study on the GIS-based analysis of the damages resulting from the befall in 1993 and 1994, which had been launched by the forest research service. The satellite-based survey of the affected areas was based on Landsat-TM data covering 1991, 1994 and 1995, which had been geometrically and radiometrically rectified before. Furthermore, a prototype for a Forest Information System was developed to support the case study, which was employed to manage both conventional forest stand data as well as results from terrestrial mapping of damages caused by the insects and information on preventive- and counter-measures. The thematic interpretation, which was based on Spectral Mixture Analysis (SMA) approaches, proved to be at least equivalent to terrestrial mapping, while it was even superior in the spatial differentiation of affected stands. Hence, it could be demonstrated that a considerable potential lies in the synoptic interpretation of remote sensing data with forest information systems for the assessment and monitoring of large-scale insect calamities and the resulting impacts. The operational success in applying the methodology to analyse insect infestations or related damages, for example after storm events, will strongly depend on the timely availability of the respective satellite data, a prerequisite which had been met for this study. However, with the advent of more sensors that can be used alternatively, we can expect the possibilities to significantly increase in the near future.

5. Employing reflectance models for estimating biophysical parameters

Regarding forest decline it was of special concern to evaluate the applicability of still experimental approaches for a remote sensing based determination of biophysical stand models. In the frame of this project experiments have been undertaken in the region of the Forstamt Morbach, which was heavily affect by the effects of forest decline (compare final report, ch. 7.3). This was achieved by means of high precision geocoded Landsat-TM data, radiometrically corrected and converted to bi-directional reflectance as described in paragraph 2 of this short summary. The underlying hybrid reflectance model Forest Light Interaction Model (FLIM) interprets forests as horizontally structured vegetation stands with patches of shading tree crowns and open areas. Results indicate the ability to derive plausible LAI- and crown closure values from Landsat-TM data for pure fir stands of different age. However, unambiguous separation of damaged and undamaged stands was neither possible through the modelled parameters of yellowness via the infinite red reflectance, nor through LAI or crown closure. Based on these results, a modified forest reflectance model was developed by the Remote Sensing Department by coupling FLIM with available leaf- and stand reflectance models (Prospect, SAIL). First results indicate a better characterisation of forest parameters through crown LAI, leaf chlorophyll and water content; further research is on the way in the frame of the Sonderforschungsbereich 522 "Umwelt und Region" which was recently implemented at the University of Trier. Summarisng, it can be stated that such new methodological approaches are promising, but not yet operational.

6. Mapping stand types as support for forest inventory

The aim of this task was to determine the stocking densities in 3 forest compartments of the Forstamt Morbach (Rhineland-Palatinate, W-Hunsrück) by means of multitemporal Landsat-TM data. Due to the typical low mountain range characteristics of these beats a precise, topography-based radiometric correction was essential. Again, the available forest inventory

information has been employed as auxiliary data via a Forest Information System. The fully corrected remote sensing data sets from 1990 and 1995 have undergone a GIS-based stand specific spectral analysis and were then transformed in thematic maps with a standard multispectral classification. Apart from birch-forested wetlands and douglas fir pole stands accuracies were generally better than 90%. It is likely that incorporating imagery from different phonological stages would also lead to improvements for the problematic classes. Summarising, the classification results for both years represent a full coverage of the stocking parameters for the 3 investigated compartments. Polygons representing homogeneous stand information generated with a raster-to-vector conversion algorithm contain up-to-date information that will facilitate noticeably higher accuracy during terrestrial surveys. Comparing both data sets (1990 and 1995) it was also feasible to retrieve information on variation of the stand situation and hence to actualise such data during the accustomed acquisition period of 10 years. Regarding the unavoidable cuts in costs for future terrestrial surveys incorporating operational satellite data opens a useful alternative. However, achieving operationality is a vital prerequisite for implementation; in this context, the meanwhile initiated Forest Information System of Rhineland-Palatinate (WÖFIS) receives certainly particular significance.