REMOTE SENSING BASED FOREST MAP OF AUSTRIA AND DERIVED ENVIRONMENTAL INDICATORS

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ABSTRACT

Detailed information on the Austrian forests is regularly provided by the Austrian national forest inventory on a plot sample basis. However, for environmental assessments and international reporting, in addition, up-to-date information on the forests at a wall to wall basis, as well as derived environmental indicators is required. Therefore, within the GSE-Forest Monitoring initiative (www.gmes-forest.info), the following information is obtained from remote sensing data for whole Austria:

- Forest map according FAO nomenclature definition
- Land Cover statistic outside forests
- Derived forest environmental indicators

According to national reporting obligations towards UNECE/FAO, MCPFE and EEA the results are based on the FAO nomenclature definition of "forest" which differs from the national forest definition, e.g. regarding minimum forest area and minimum crown cover. For the generation of the Austrian forest map, high resolution multi-spectral satellite image data and very high resolution digital aerial imagery were combined. According to the requirements of the Austrian Federal Environment Agency, environmental indicators at the landscape level were derived from the forest map.

For the quantification of land-cover types outside of the forests an area frame sampling approach was implemented with regular distribution of the area frames over whole Austria in a distance of 20km by 20km, which gives quantitative information on the land cover according IPCC / FAO nomenclature definitions.

The area frame sampling results were also used for an independent accuracy assessment of the forest map. The results show a high overall accuracy of 96.6% for the derived Austrian forest map.

Keywords: Forest Map, Austria, FAO nomenclature, Area Frame Sampling, environmental indicators

1 INTRODUCTION

In Austria, standardized monitoring of the forests is currently performed by the Austrian national forest inventory on a plot sample basis. To provide in addition to this statistical data forest related information on a wall-to-wall basis, remote sensing methods were developed within the GSE-Forest Monitoring service "CORINE spatial refinement" (http://www.joanneum.at/en/fb3/dib/projects/gse-forest-monitoring.html). The work is performed by Joanneum Research (service provider) and the Federal Environment Agency of Austria (user organization).

2 FOREST MAP OF AUSTRIA

2.1 NOMENCLATURE DEFINITION

The forest map is based on the nomenclature definitions of the Food and Agriculture Organization of the United Nations (FAO, 2004). The main reason for using the FAO nomenclature definition is to facilitate the various reporting requirements at the international level. The detailed definition of forest by FAO (2004) is:

"Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use".

Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10 percent and a tree height of 5 m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Included are also forest roads, other small open areas and forest in protected areas as well as windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20 m.

Compared to the Austrian national forest definition there are the following main differences:

- Minimum crown cover of 10% instead of 30%
- Minimum area of 0.5 ha instead of 0.1 ha
- Minimum width of 20m instead of 10m.
- Minimum height of 5m instead of specification at the species level (mountain pine stands and greenalder stands at the subalpine timber line are therefore excluded from the forest area).

The derived forest map therefore complements the statistical information of the national forest inventory, which is based on the national definition of forests.

2.3 REMOTE SENSING AND ANCILLARY DATA SETS

To meet the high accuracy specifications of the Austrian environment agency (compare below), the multi-spectral satellite remote sensing imagery were combined with very high resolution airborne remote sensing data.

Satellite remote sensing data

For the classification, mainly multi-spectral scenes from SPOT satellites with spatial resolution of 10m to 20m were used, which were provided by ESA free of charge for the GSE - project. In addition, selected ASTER multi-spectral scenes with 15m spatial resolution and multi-spectral ALOS data with 10m spatial resolution were used. In addition, fused panchromatic – multispectral Landsat ETM+ data was used in remaining areas e.g. cloud covered areas. All satellite scenes were ortho-rectified with the Remote Sensing Software Package Graz (http://dib.joanneum.at/rsg/). A digital elevation model was used to take into account geometric distortions caused by the topography. In the course of the ortho-rectification, the satellite scenes were resampled by cubic convolution to a spatial resolution of 12.5 meters per pixel. The achieved geometric accuracy is in the order of one picture element for all scenes.

Airborne remote sensing data

For Austria, a complete coverage of digital ortho-photos is available. Most areas are covered with true-colour acquisitions, whereas for some areas, only panchromatic acquisitions are available. For the classification of the wall to wall forest map image mosaics with a spatial resolution of 1m were used. The radiometric characteristics of the aerial imagery depend amongst other parameters on the viewing geometry, film material, shutter speed and acquisition dates. These effects lead to strong variation of radiometric characteristics within the image data. For this reason the aerial images only could be used to derive a texture homogeneity criterion for the classification and for the visual revision of the classification results.

The aerial images were provided for whole Austria by the Federal Ministry of Agriculture, Forestry, Environment and Water Management.

Digital Elevation Model

More than 60 per cent of Austrias territory is mountainous with mountain summits reaching heights of more than 2,000 metres.

Data on the topography is therefore required for the geometric pre-processing of the satellite data (ortho-rectification) and for the radiometric pre-processing (topographic normalisation) as described below.

The Federal Ministry of Agriculture, Forestry, Environment and Water Management therefore provided a digital elevation model with 10m spatial resolution for whole Austria for the purposes of the project.

2.3 SELF CALIBRATING TOPOGRAPHIC NORMALISATION

The topography does not only affect the geometry of the remote sensing imagery but has also a significant influence on the radiance measured by the satellite (Schardt, 1987). This effect is caused by the local variations of view and illumination angles due to the terrain and thus is particularly critical for applications in mountainous regions. To overcome this problem, several radiometric correction procedures are described in the literature. Earlier correction methods were based on the lambertian assumption, i.e. the satellite images are normalized according to the cosine of the effective illumination angle. However, most objects on the earth's surface show non-lambertian reflectance characteristics. Further, the reflection properties differ significantly for different land cover types as shown in the following table for an alpine area (Gallaun, 2006).

Table 1. Correlation coefficient of the radiance and the cosine of the incidence angle for selected land cover categories for Spot5 spectral bands

Land Cover Category	SWIR	NIR	Red
Alpine meadow	0.89	0.70	0.63
Greenalder	0.89	0.90	0.63
Coniferous, thicket	0.54	0.58	0.58
Subalpine grassland	0.74	0.64	0.30
Dwarf Shrubs	0.78	0.66	0.46

As the above table shows, the integration of land cover information is essential for appropriate correction of the topographic effects.

Therefore, the following self calibrating topographic normalization method has been developed within the project. First, from the multi-spectral remote sensing bands, ratios are calculated, which show less dependence on illumination effects then the original bands (the illumination effects caused by the topography are to a large extend multiplicative). In the **first iteration,** these ratios are used for an unsupervised classification which divides the whole image into spectrally distinct categories. For each of the derived categories, the so called minnaert-constant is calculated separately by linear regression of the processed original bands and parameters derived from the digital elevation model (for detailed descriptions of the minnaert equations see e.g. Colby, 1991). The mean of the calculated class-specific minnaert constants is then used for a first topographic normalization. The resulting topographically corrected bands are used in the **second iteration** as input for an unsupervised classification which subdivides the whole image again into spectrally distinct categories. For each category, the minnaert constants are determined and the mean of the minnaert constants is used for the topographic normalisation. The resulting corrected bands are used in the **third iteration** for an unsupervised classification. For each of the categories the minnaert constant is calculated. Against in the second iteration, the class specific minnaert constants and not the mean of the minnaert constants, is used for the final topographic normalization.

As the result of this iterative procedure, the topographic effects are corrected separately for the different land cover types.

The procedure is fully automatic and no reference data is required, which is especially important, when large numbers of satellite scenes have to be processed.

2.2 TEXTURE HOMOGENEITY CRITERION

According to the size of trees and their distribution, forested areas show a high variation of gray values in very high resolution remote sensing data. To use this textural information in the classification process, the following new texture homogeneity criterion is used.

First, a parameter which quantifies image texture is derived from the image data over specified directional neighborhoods. The selection of the texture parameter and the definition of the directional neighborhood depend on the object and image characteristics.

For the current application, the coefficient of variation was used as texture parameter. This parameter was calculated for the following directional neighborhoods:

Eight wedges, each covering 45° of a circle with 16m diameter (0°- 45°, 45°-90° and so on) and one full circle, with diameter of 6m. No further directional neighborhoods were used in the current application because of the computationally intensive calculations (wall-to-wall cover of whole Austria with 1m spatial resolution).

Secondly, the minimum of the derived texture parameters of all specified directional neighborhoods is calculated.

The main advantage of this texture homogeneity criterion compared to standard texture-features is, that there are sharp borders between homogeneous and inhomogeneous regions.

2.4 CLASSIFICATION

The separation of forests from non-forested areas can easily be achieved by combing spectral features derived from satellite data and textural features calculated from aerial photos. The critical issue is thereby not the applied classification procedure, but the appropriate pre-processing of the data and the derivation of features which optimally represent the required information.

Various different methods can be applied for the classification task. However, classification methods which require reference data sets e.g. concerning crown cover, such as regression estimators, could not be used because no appropriate reference data sets were available for each of the scenes. In respect of a cost effective approach therefore, a knowledge based classification with the following decision tree was applied.

- assign areas above a defined height threshold to non-forest (regional varying height of the subalpine tree-line)
- Assign areas with slope above a defined threshold to non-forest
- On the basis of the homogeneity criteria, assign homogeneous areas which are not shadowed to non-forest
- assign areas with reflectance below a defined threshold in the NIR spectral band to non-forest (water and other land cover types)
- assign areas with reflectance above a defined threshold in the green spectral band to non-forest
- the remaining areas are assigned to forest

The classification is performed with different thresholds because of different acquisition dates of the remote sensing data.

In the next processing step, the pixel-based classification result is aggregated according to the nomenclature definitions by application of morphological operators.

Finally, the accuracy of the classification is improved by on-screen visual revision of the classification result based on the ortho-photo mosaic. This enhancement is particularly useful in suburban areas and at the alpine tree-line which are characterized by a complex mixture of various land cover types.

2.5 AREA FRAME SAMPLING

To provide in addition to the forest area map also quantitative information for other land cover categories (e.g. green-alder, mountain pine, succession areas etc.), an area frame sampling approach was implemented within the project. The area frames were distributed systematically over whole Austria in a regular distance of 20km in north-south and east-west direction. In all area frames (each covering 2,5 km by 2,5 km) the land cover was visually interpreted for 100 sample points. This approach gives statistical information on specific land cover types including transition areas between forests and non-forested areas. Further, this approach allows a cost effective monitoring of land cover and land cover changes in the future.

2.6 ACCURACY ASSESSMENT

Accuracy assessment was performed by automated comparison of the sample points from the area frame sampling approach and the generated forest area map of Austria.

Corresponding to the pixel-resolution of the forest area map of 12.5m, sample points within +- 12.5m of the forest border were excluded from the verification in order not to produce misinterpretation caused by geometric image distortions.

Table 2. Accuracy of the forest map (in number of sample points and in percent)

Reference Classified	Forest	Non-Forest	Commission [%]
Forest	**1996**	**67**	**3,2**
Non-Forest	**132**	**3614**	**3,5**
Omission [%]	**6,2**	**1,8**	
Percent correctly classified: 96,6 %			

The accuracy assessment shows, that the requirements defined by the Austrian environment agency with an overall accuracy better than 90% could be achieved.

3 FOREST ENVIRONMENTAL INDICATORS

To facilitate international reporting obligations, the forest area map was used to derive forest environmental indicators at a wall-to-wall basis. The assessments are performed both at a Grid basis with a resolution of 1km by 1km and at the community level.

3.1 LANDSCAPE LEVEL SPATIAL PATTERN OF FOREST COVER

The landscape-level spatial pattern of forest cover (MCPFE indicator 4.7; EEA BDIV06a; Alpine Convention Indicator C3-2) gives information on the size, shape and spatial distribution of forest areas / patches in a landscape and reflects the potential of a landscape to provide forest habitats.

In close cooperation with the Austrian Environment Agency, following quantitative measures, which support reporting according above indicators, were derived from the forest map both at a Grid basis with a resolution of 1km by 1km and at the community level:

- Forest area percentage
- Number of forest patches
- Forest core area
- Lengths of forest borderlines
- Ratio of lengths of forest borderlines and forest area

Other measures such as e.g. fractal dimension were not selected because of interpretability reasons.

3.2 FOREST FRAGMENTATION

The UN Convention on Biological Diversity considers fragmentation to be a major threat to habitats and species populations. This is reflected in the Pan-European Biological and Landscape Diversity Strategy as well as in the European Community Biodiversity Strategy and the EC Habitats Directive. An agreed definition of un-fragmented area is so far not available on a pan-European level (MCPFE 2003). By intersecting the forest area map with data on the transportation network, the Austrian Environment Agency derived the indicator "Fragmentation of ecosystems and habitats by transport and infrastructure" (related to EEA TELC02 and to Alpine Convention indicator C2-1).

The results clearly show the current situation of the forest fragmentation in Austria and can be used as basis for future quantitative monitoring of changes in forest fragmentation.

4 CONCLUSIONS

The achieved results complement already available information collected by the Austrian National Forest Inventory by providing in addition to the statistical data a wall-to-wall forest map of Austria with high thematic and geometric accuracy. To facilitate international reporting obligations, the mapping was based on FAO forest definitions. Furthermore, according to the requirements of the Austrian Environment Agency, statistical information on land cover was derived by area frame sampling. This approach allows an appropriate and cost effective method for future monitoring of land cover and land cover changes. Additionally, specific environmental indicators defined by the Austrian Environment Agency were derived.

From a methodological point of view, a new "self calibration topographic normalization method" and a new "texture homogeneity criterion" were developed within the project.

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