Modelling the distribution of organic carbon stocks in floodplain soils with VHSR remote sensing data and additional geoinformation

Suchenwirth, L., Kleinschmit, B. and Förster, M.

Technische Universität Berlin, Institute of Landscape Architecture and Environmental Planning, Department of Geoinformation Processing; Office EB5; Strasse des 17. Juni 145, 10623 Berlin, Germany
Contact details: 0049 (0)30 31479096; leonhard.suchenwirth@tu-berlin.de

Abstract

Floodplain soils play a crucial role when storing carbon; but there are few data on the carbon stocks in these soils compared to other terrestrial ecosystems. There is still no scientific basis for the generation of large scale soil maps showing the distribution of organic carbons in floodplain soils which are based on remote sensing and additional data. The research area is the Donauauen National Park in Austria. In a first approach the variables water regime, the vegetation, the relief position and the content of clay and iron oxides were identified to have an effect on the carbon content. In this paper, an overview of the modelling approach will be presented. The classification of vegetation parameters such as vegetation type, age, density of trees per hectare, a combination of pixel and object-based classifications shall be explained and discussed in detail. The results will be integrated into a rule-based classification process, using fuzzy logic to integrate additional data and expert knowledge into the spectral classification.

Keywords: *Floodplain soils, Ikonos, Riparian Forests, Object-based Image Analysis, Carbon, Danube River*

1. Introduction

Floodplain soils play a crucial role in the storage of carbon, and thus for the mitigation of climate change, as indicated by the IPCC 2000. According to Cierjacks *et al.* 2010, carbon stocks in the Danubian floodplain soils are huge (up to 254 tons per hectare) in comparison to other terrestrial ecosystems. Nevertheless, there are few data available on the carbon stocks in these soils. Remote sensing data have been used for quite some time for the detection of soil characteristics (McBratney *et al*. 2003). However, there is still no scientific basis for the generation of large scale soil maps showing the distribution of organic carbons in floodplain soils which are based on remote sensing and additional data.
Since expert knowledge regarding the relation between vegetation as well as several geofactors and the carbon stocks in test area is partly available as verbal description, which often contains cognitive uncertainties and is imprecise, fuzzy logic represents a possibility to express these vague statements in a mathematical framework as a degree of membership to a fuzzy set (Zadeh 1983).
Object-based image analysis has been on the rise in the recent years with the improvement of software packages, especially for the classification of high-resolution imagery such as Ikonos, QuickBird or GeoEye satellite data or orthophotos. For the object-oriented classification of forestry-specific parameters there have been image segmentation approaches with self-programmed software (e.g. Kubo *et al.* 2005, Kubo *et al.* 2007), but there are also approaches with commercial software (e.g. Chubey *et al.* 2006).

The overall goal is to develop a knowledge-based method to model the spatial distribution of organic carbon stocks in floodplain soils, using very high resolution remote sensing data and the auxiliary information. This method is intended to support large-scale mapping of organic carbon stocks in floodplain soils. Knowledge from soil science can be regionalised and be used for the increased requirements of landscape and environmental mapping, especially regarding the climate function of soils.

2. Study Area and Data

2.1 Research Area

The research area is situated in the Donauauen National Park in Austria, which is situated along the river Danube between Vienna, Austria and Bratislava, Slovakia. It preserves the last remaining major wetlands environment in Central Europe. Here, the Danube is still free flowing and is the lifeline of the National Park. The National Park was founded in 1996, and has an area of about 9,300 hectares. The research area is situated in the west of the National Park, between the villages Orth an der Donau, Haslau and Maria Ellend. For the classification of vegetation parameters, a test area of approximately 2.1 km² has been chosen from the Ikonos scene (Figure 1).

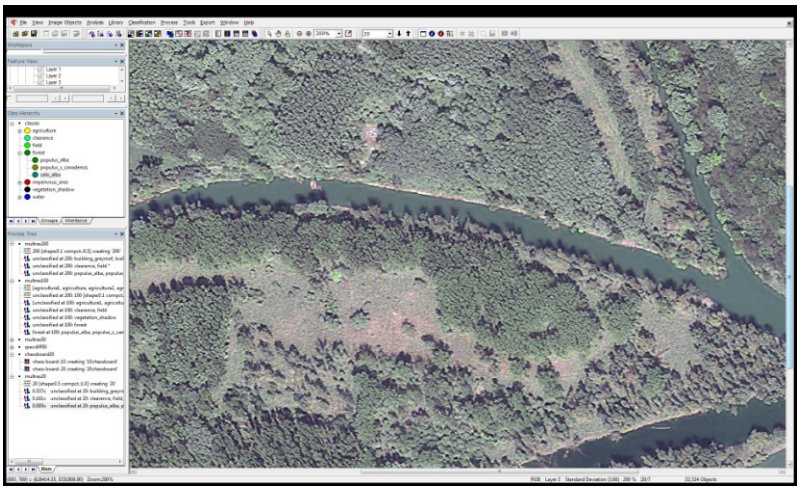

Figure 1: *Test area of the research area, with clearances, salix alba, populus alba and populus x canadensis*

2.2 Data

Ikonos data from the 22nd of April 2009 have been ordered. By the time the image was taken, leaves of the vegetation have been sprouted completely. The Ikonos-2 data set consists of single-band panchromatic imagery (450 to 900 nanometers (nm)) with a spatial resolution of 1 by 1 m, and 4-band multispectral imagery with a spatial resolution of 4 by 4 m divided into the following spectral bands: blue (445 to 516 nm), green (506 to 595 nm), red (632 to 698 nm), and near-infrared (757 to 853 nm). The total Ikonos scene has a size of approximately 49 km².

Besides the satellite data, following auxiliary data are included in the approach: historic Austro-Hungarian maps from the 18th and 19th century (to retrieve information about former courses of the river), actual topographic maps, a digital elevation model (DEM) gained by airborne laser scanning. , biotope maps and a geomorphologic map and for verification orthophotos from 1997 and 2007, as well as a forestry inventory cadastre from 1998/1999, and field survey data from 2009.

3. Methodology

In a first approach by Cierjacks *et al.*2010, the variables water regime, the vegetation, the relief position and the content of clay and iron oxides were identified to have an effect on the carbon content. Two different types of sedimentation areas can be distinguished: a) dynamic areas, stocked with younger trees and a higher number of trees, and due to frequent inundations with a high flow velocity a higher number of soil horizons; and b) stable areas with a lower number of trees, a higher distance to the river, and due to a lower flow velocity during inundations a lower number of soil horizons.

Based on these findings the overall goal is to develop a knowledge-based method to model the spatial distribution of organic carbon stocks in floodplain soils, using very high resolution remote sensing data and the auxiliary information. This method is intended to support large-scale mapping of organic carbon stocks in floodplain soils. Knowledge from soil science can be regionalised and be used for the increased requirements of landscape and environmental mapping, especially regarding the climate function of soils.

The methodology is based on spectral and knowledge-based classification. In order to determine vegetation parameters, a combination of pixel and object-based classifications will be used. For the object-based classification, the commercial software Definiens Developer 7.0 has been used (www.definiens.com). The results will be integrated into a rule-based classification process, using fuzzy logic to integrate additional data and expert knowledge into the spectral classification.

Following of the vegetation parameters will be explained and discussed in detail:

-Vegetation type: On the aerial imagery of the study area, five vegetation units could be differentiated visually: *Salix alba, softwood floodplain forests, populus alba, populus x canadensis and hardwood floodplain forests.* In a study done by Chubey *et al*. 2006 for Alberta, Canada, the IKONOS a combination of NIR and panchromatic bands were used to determine spruce, pine and aspen stands.

-Density of trees per hectare: The density of trees per hectare can be compared to the crown closure parameter described by Chubey *et al.* 2006, which used the Ikonos blue band as well as the standard deviation of the direction of sub-objects for the determination of the crown closure of pines.

-Age: As Chubey *et al.* 2006 state, stand age cannot be remotely sensed directly. Nonetheless, variables related to structure and composition can vary with maturity, such as the Normalized Differenced Vegetation Index (NDVI). For the interpretation of aerial images, the detection age classes of trees has been described by AFL 2003.

Besides the vegetation, there are also plenty of other parameters that can be taken into account. Figure 2 depicts the concept for the modeling of organic carbon stocks in floodplain soils.

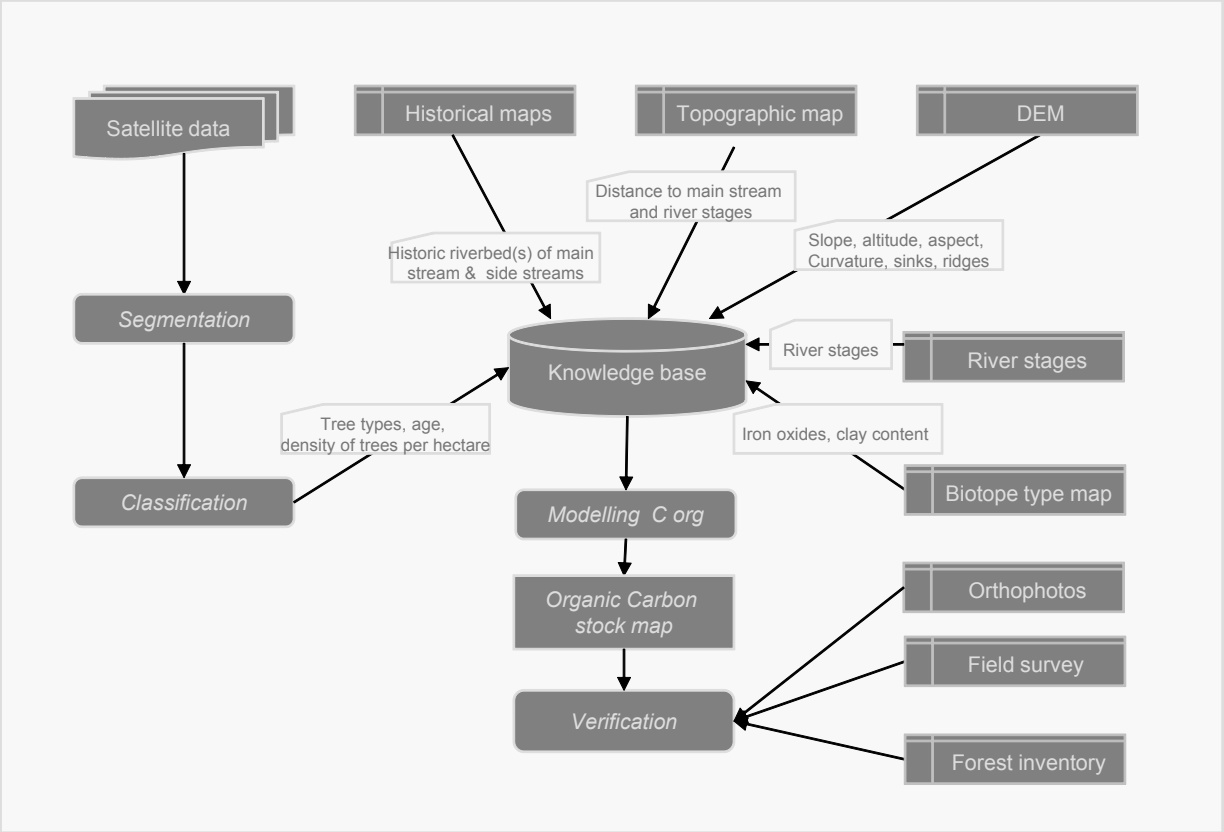

Figure 2: *A concept for the modelling of organic carbon stocks in wetland soils*

4. Results and Discussion

Before classifying the test area (Figure 1), the image is segmented into image objects. The segmentation can be influenced by parameters such as spectral value as well as shape of the image objects. In order to determine the proper segmentation parameters, an experimental and iterative segmentation and classification process had to be implied. For the Ikonos scene under investigation, the task was to differentiate between various types of trees, these are *salix alba, populus alba, and populus x canadensis*. Besides these tree types, also water, impervious areas clearances and agricultural area have been defined by samples. Figure 3 shows a classification, with a larger segmentation, summing up small groups of trees.

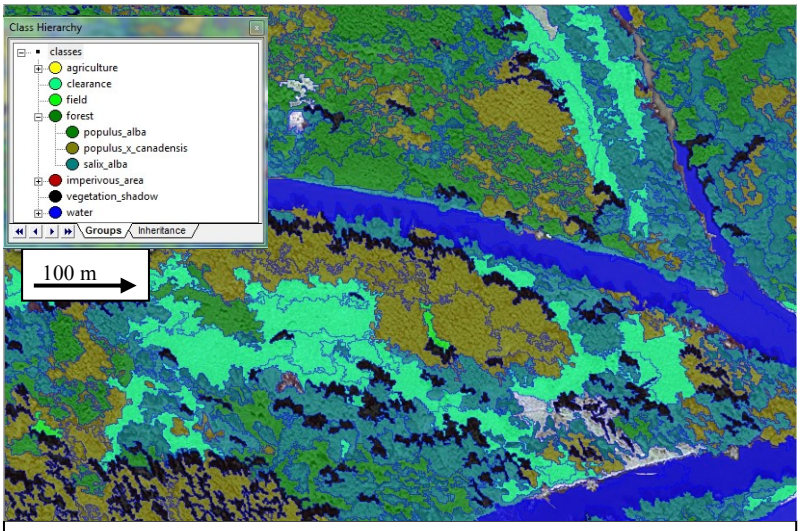

Figure 3: *Classification based on multiresolution segmentation with scale parameter 100*

So far, results could not be validated statistically. Apart from the vegetation type, other indicators such as the crown closure have not been included into the classification process.

In a visual interpretation of results, the classifications of water, clearances and fields are very satisfying, whereas the correct classification of forest vegetation types turns out to be difficult due to the overlapping spectral values of *populus x canadensis, populus alba* and *salix alba.*

In the area north of the river, a consistent stand of *populus alba* has been partly classified as *populus x canadensis*, as shown in Figure 3.

It turns out that spectral values of the classes are slightly overlapping. Inside the floodplains, there are fluent transitions between the various vegetation zones, and mixed classes have not been promising so far.

5. Conclusions and Outlook

In the upcoming research, it is planned to analyze the density of trees per hectare. This can be achieved by chess board segmentation with a scale of 100, i.e. 100 by 100 meter squares will be analysed.

For the determination of the age of the tree populations, the NDVI can be used as an additional segmentation layer.

More ahead in the future will be the integration of additional information into the classification process. The digital elevation model will have to be integrated into the classification and modelling process, with apt parameters to be found. Also the former river arms, derived from historical topographic maps, will have to be used. For the assessment of the relevance of the single parameters, the software package C5 can be used.

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