Chapter 21
Topsoil Organic Carbon Content

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Abstract Soil organic carbon (SOC) is a key soil component. SOC stores large amounts of carbon and it also affects water fluxes as well as the availability of nutrients. Soil water fluxes are impacted by SOC directly due to its effect upon soil hydraulic parameters. Also many indirect effects of SOC upon water fluxes have to be recognised, such as the impact upon plant growth and nitrogen turnover. SOC maps for all modelled soil layers in the DANUBIA simulation system for the Upper Danube watershed are therefore a necessary prerequisite to model plant growth, soil nitrogen turnover and soil water fluxes. For the majority of the Upper Danube watershed, these maps were easily derived from the 1:1,000,000 soil map (BÜK 1000, BGR, Bodenübersichtskarte 1:1 Million. Bundesanstalt für Geowissenschaften und Rohstoffe, Berlin, 1995). The BÜK 1000 distinguishes 33 different soil types within the Upper Danube catchment. Soil properties including SOC content are associated to soil-type-specific pedogenetic horizons. The SOC content and the C/N ratios for each of the soil layers were derived as a weighted mean of the SOC contents given for the BÜK 1000 soil layers. The BÜK 1000 does not cover areas outside of Germany. For these mainly alpine regions, the SOC contents were estimated using a three-step rule-based approach by (a) establishing a statistical relationship between soil-type unit and elevation, (b) estimating the SOC based on the assigned soil type and (c) selecting the predominate soil type for grid cells with multiple soil types (majority principle).

Keywords GLOWA-Danube • DANUBIA • Global change • Soil organic carbon • SOC

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21.1 Introduction

Soil organic matter is one of the main components of soils as it stores large amounts of carbon and contains important amounts of macronutrients (nitrogen, N, phosphorus, P, and potassium, K). In many ecosystems the N and C availability control the overall soil turnover and functioning (Batlle-Aguilar et al. 2011). In this context the C/N ratio is of particular significance because it determines the availability of microbial nitrogen. Moreover, soil organic matter or soil organic carbon (SOC) content is an important proxy variable to estimate infiltration capacity as increasing SOC contents are associated with larger aggregate stability, larger unsaturated hydraulic conductivity as well as higher biological activity affecting macro-porosity (Fiener et al. 2013).

In general SOC and associated N are important parameters affecting the water balance in the Upper Danube basin via their potential effect on plant growth and hence transpiration as well as their effect on partitioning precipitation into surface runoff and infiltration. Therefore, any change in climate and land use affecting SOC contents may result in a substantial climate feedback. Besides indirect effects on water balance, the SOC and associated N contents are essential for N leaching from the vadose zone, the latter representing one of the most important hazards for groundwater quality in the basin.

21.1.1 Data Processing

To model N turnover and N leaching (SNT; Chap. 38), spatially distributed SOC amounts in all three modelled soil layers (0–20, 20–80, 80–200 cm) are needed. Given the spatial resolution of 1 km grid cells used in DANUBIA, the German 1:1,000,000 soil map (BÜK 1000, BGR 1995) is most suitable. The BÜK 1000 does not cover the study area outside of Germany (Fig. 21.1). Thus, the soil layer-specific SOC contents in the remaining, mostly mountainous areas outside of Germany were derived by extrapolating the BÜK 1000 data to the entire basin.

Overall a three-stage preprocessing of the BÜK 1000 was applied to assimilate the data into the DANUBIA modelling system:

(a) A rule-based approach was used employing statistical relations between the soil-type units in the southern, alpine regions in the BÜK 1000 and elevation taken from the project digital terrain model.
(b) Based on the derived rules, elevation-specific soil types with their associated SOC contents were estimated for the regions not covered by the map.
(c) Due to the spatial resolution of DANUBIA, it is not possible to include a smaller-scale soil variability as partly represented in the BÜK 1000. If soils are not homogeneous within a DANUBIA proxel, the SOC content is taken from the major soil type within the proxel (majority principle).

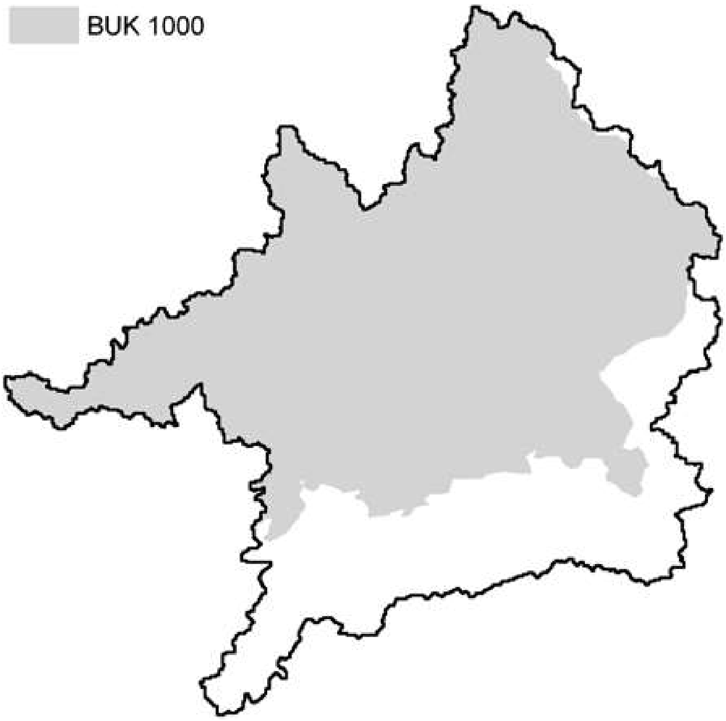


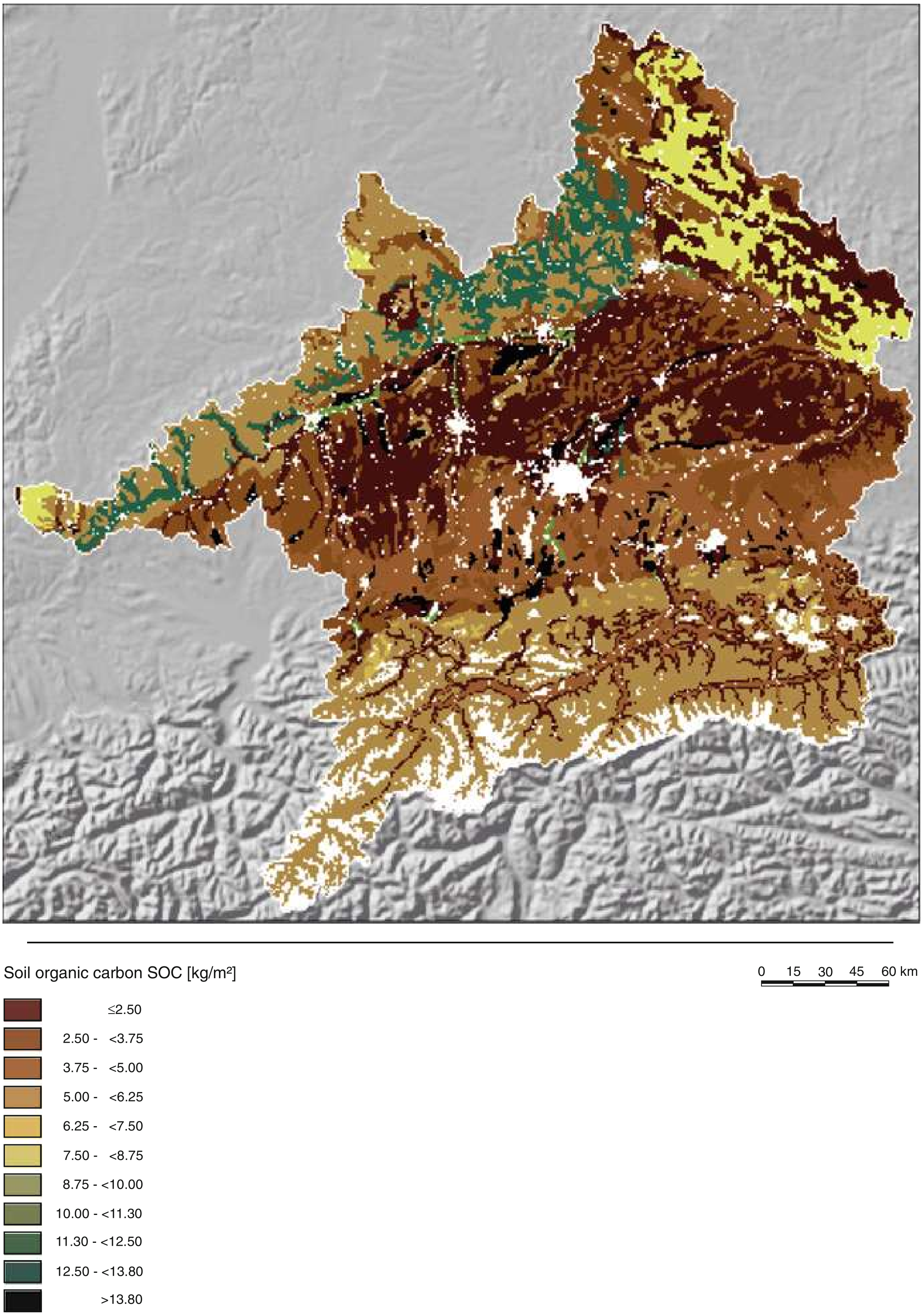
Fig. 21.1 Coverage of the Upper Danube basin by BÜK 1000 (BGR 1995)

The BÜK 1000 represents 33 different soil types within the Upper Danube basin. Soil properties including SOC content are associated to soil-type-specific pedogenetic horizons. The depths of these horizons differ spatially. Hence, to meet the DANUBIA requirement of consistent soil layers (0–20, 20–80, 80–200 cm), it was necessary to reprocess the soil depth profiles. Therefore, the given horizon-specific SOC contents were weighted by the proportion of the respective soil layer and the weighted average was used for parameterisation of the three soil layers. Analogously the C/N ratios were converted to the soil layer system.

21.2 Results

Map 21.1 presents the topsoil SOC amounts (0–20 cm) as used in DANUBIA for modelling N turnover and N leaching. In order to improve the readability of the map, the SOC contents were categorised in 11 classes.

In general, most topsoil SOC amounts are below 6.25 kg m^{-2} (Fig. 21.2) which results in a SOC content of 2.3 % (assuming a typical bulk density of 1,350 kg m^{-3}). A latitudinal change of topsoil SOC amounts can be identified from south to north. In the southern, mostly alpine part of the basin, topsoil SOC amounts are relatively high in poorly developed soil profiles on relatively steep slopes and climatic conditions favouring topsoil SOC accumulation. However, the values shown here for these areas may be associated with a high degree of uncertainty, as generally little soil information is available for alpine areas, and, more importantly, most of the SOC values presented here are based on a simple extrapolation approach. Since



Map 21.1 Topsoil organic carbon content (Data source: BÜK 1000, BGR 1995)

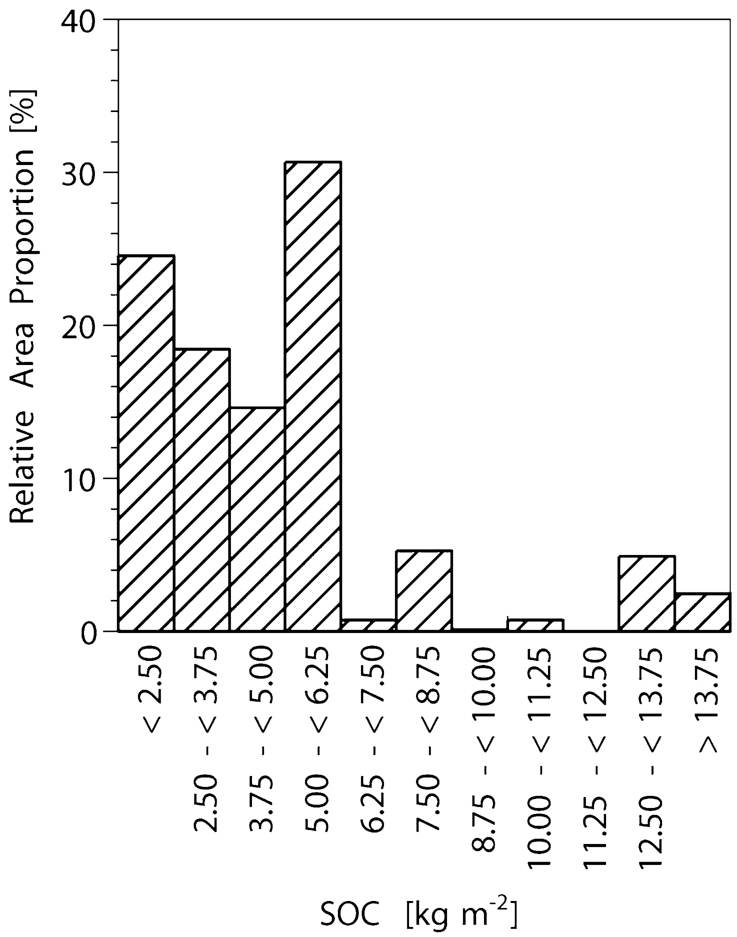


Fig. 21.2 Relative area proportion of different soil organic carbon (SOC) amount classes in the Upper Danube basin based on BÜK 1000 (BGR 1995)

the map is used to model N turnover and especially N leaching, this fact may pose a problem particularly along the inner-alpine valley floors. Here the map indicates alpine soils, while intensive agricultural use may occur with high fertiliser inputs (e.g. along the Inn valley). However, as proxels with agricultural use are relatively rare within the alpine region (see land use, Map 9.1), the chosen method should result in a reasonable model input for the vast majority of proxels in this area.

North of the Alps, in a zone where climatic conditions do not allow for intensive cropping, a grassland zone exists with relatively high topsoil SOC amounts. The lowest topsoil SOC amounts are associated with an area of intensive cultivation between this grassland zone and the Danube River. Partly soils with SOC contents below 1 % can be found. North of the Danube River, the SOC pattern becomes more patchy, with generally higher topsoil SOC amounts in the north-western to northern part (Swabian Jura and Franconian Jura) as compared to the north-eastern part (Bavarian Forest and Bohemian Forest). Apart from a mostly latitudinal sequence of topsoil SOC amounts, it is worth noting that areas with highest SOC values are located along the larger valley floors, where high groundwater levels reduce SOC mineralization. This is most pronounced in the (former) peat lands, e.g. the Donaumoos.

References

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