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Soil inventory in forests of the Biosphere Reserve Wienerwald
Water shortage due to climate change? A simple application of the data

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Abstract

The Biosphere Reserve Wienerwald is one of the biggest continuous areas of deciduous forest in Central Europe. During the years 2009 through 2012 a soil survey was performed on 488 plots mainly focusing on the core zones. It consisted of a simplified profile description, photographic documentation and sampling of genetic mineral soil horizons.

As one example for the broad applicability of the obtained data, two plots were selected and used to generate a simple water balance for 3 different temperature scenarios. The available water storage capacity of the soil was estimated using density of dry fine soil, texture class, content of organic carbon and coarse material content. The potential evapotranspiration was calculated with the help of temperature and location. Furthermore it was assumed that there will be no change of the precipitation regime in the future.

It became apparent that an increase of already +3°C compared with present climate conditions partly results in a complete depletion of the plant available water reservoir during the summer and autumn months. If additionally the annual distribution of precipitation will shift towards the winter half-year, as expected in literature, the possible impact may be even worse.

Keywords

soil survey, monitoring, Biosphärenpark Wienerwald, available water storage capacity, potential evapotranspiration, water balance

Introduction

The Biosphere Reserve Wienerwald

The Wienerwald is one of the biggest continuous areas of deciduous forest in Central Europe extending across the two federal states of Vienna and Lower Austria covering an area of approximately 1000 km². It was admitted as a biosphere reserve in 2005 by UNESCO, dividing it into a mosaic of core-, buffer-, and transition zones.

The whole area can be roughly assigned to two main geological zones which is reflected in different land forms. The northern area is part of the Flysch zone showing mainly smooth hillsides whereas the southern part belongs to the Northern Limestone Alps with in general more steep rugged terrain. (See figure 1)

The soil inventory project

The diversity of soil types in the forests of the Biosphere Reserve Wienerwald was surveyed during the years 2009 through 2012 on behalf of the following partners: Biosphärenpark Wienerwald Management GmbH, Österreichische Bundesforste AG, Forstamt und Landwirtschaftsbetrieb der Stadt Wien (Ma 49) und RU5- Land NÖ.

This survey was based on a grid of roughly 1600 monitoring plots existing in the core zones where a conventional forest inventory expanded by samples of vegetation and coarse woody debris is performed every 10 years.

In a first stage, every fourth plot of this monitoring grid was selected, resulting in 423 soil sampling plots, where general site characteristics were assessed and a description of the soil profile was performed. A simplified protocol was applied, which comprised assessing the sequence and thickness of horizons in humus and mineral soil, as well as soil texture, coarse material content, and presence/absence of mottling, concretions, and carbonate only in mineral soil horizons. Every soil profile was documented photographically including a close-up of the humus layer and the upper mineral soil as well as several photos of the general situation on the site.

In a second stage, 65 sampling plots were selected from managed forests in the development zones of the reserve. These were assessed according to the same field methods.

Samples were taken for chemical analysis from every genetic soil horizon in all 488 profiles. However, in order to reduce costs, only samples from two horizons of about 10 % of the plots actually have been analysed. All samples including the rest are stored in a soil bank and are available for analysis on demand. This approach is cost efficient and allows additional chemical analyses when required later.

The data have a wide field of application. Re-sampling the same plots allows monitoring of changes in the soil carbon pools after abandonment of forest management. A comparison with carbon pools in managed forests seems to be possible, when site characteristics are considered. Furthermore the data may serve as a base for a modelling of vegetation changes caused by a change of climate or nutrient status. As an example for the wide applicability we did an exercise with the *available water storage capacity* (AWSC) as the set of assessed parameters is sufficient for a rough estimate of the AWSC.

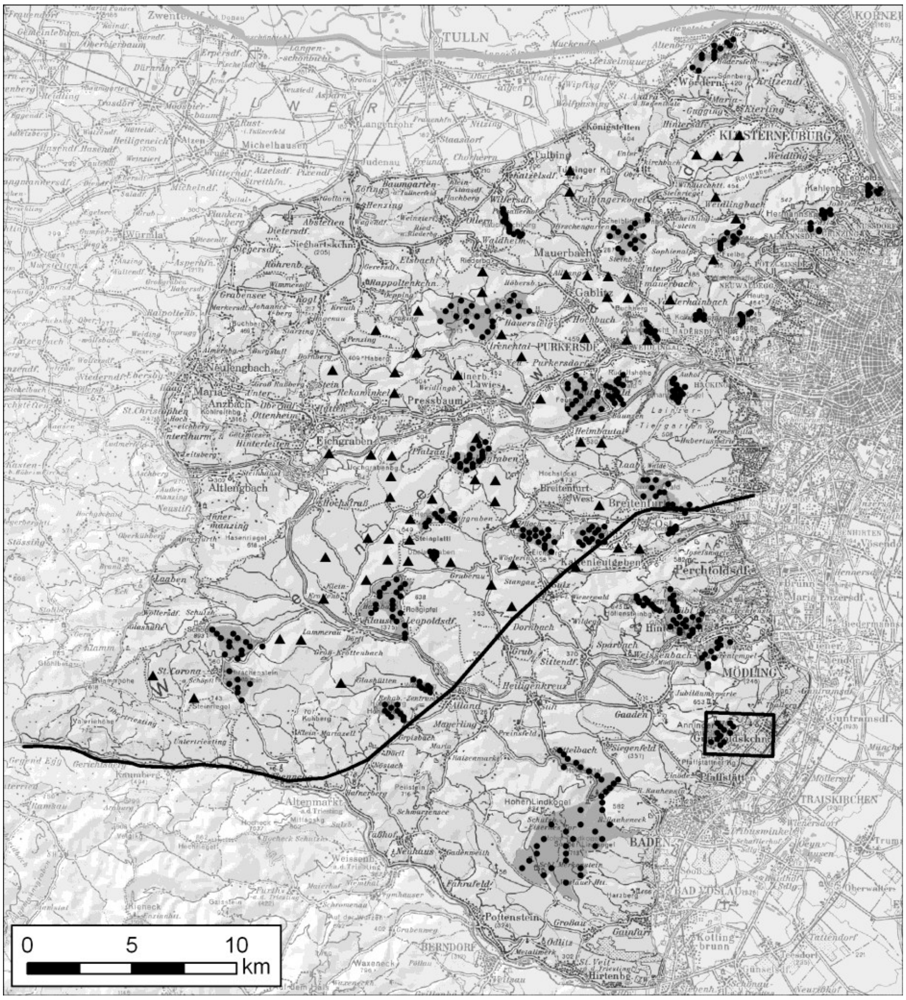

Figure 1: The Biosphere Reserve Wienerwald with the core zones and the border delineating Flysch- and Limestone areas. Soil inventory plots in the core zones are marked by dots. Soil inventory plots in the managed forests are marked by triangles. Core zone Anninger Tieftal is indicated by rectangle (see also figure 2). (Base map: Biosphärenpark Wienerwald Management GmbH)

Objectives of the study

As an example for the possible further utilisation of the soil inventory's data, two plots from one of the core zones were picked out exemplarily to demonstrate the effect of possible climate scenarios on the water balance of soils with different available water storage capacity.

We applied a simplified version of the water balance only using the following input variables:

- Potential evapotranspiration (PET)
- Precipitation
- Changes in soil water storage

This simple approach ignores other factors of the water balance like interception, lateral fluxes in the soil, actual transpiration of the tree stands for reasons of unavailability of data.

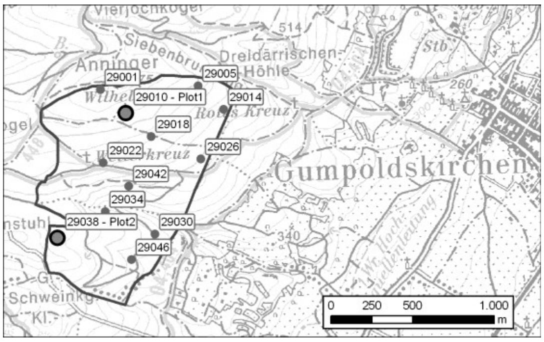

Figure 2: Situation of the core zone Anninger-Tieftal and plots 1 and 2 (Base map: ÖK50)

Methods

The study area – core zone Anninger

The core zone "Anninger-Tieftal" (see figure 2) at the western border of the Vienna basin was chosen for this specific study. The 675 m high Anninger is situated in the southern part of the reserve representing the offset of the northern Limestone Alps. It can be geologically divided into two main categories and only features two different classes of soils according to the Austrian Soil Systematics (*Österreichische Bodensystematik* - ÖBS) (NESTROY et al. 2011)

The northern part of the core zone consists of dolomites and hard limestones. In this area only Rendzic leptosols (*Rendzina)* with A-horizons showing a widely varying range in depth as well as coarse material content were found.

The southern part is built up from breccia and series of marl and limestones resulting in Calcaric Clayic Cambisols (*Kalkbraumlehm*) with more or less deep B-horizons.

At all investigated plots the humus forms uniformly were classified as Mull according to the Austrian Soil Systematics (NESTROY et al. 2011) thus the organic surface layers not being relevant for the water storage capacity.

- Plot 1 (Plot 29010)
  is situated at an altitude of 637 m a.s.l. on an undulating middle slope facing south at an inclination of 28 %. The bedrock is hard limestone (*Plattenkalk*). The current tree canopy solely consists of European beech (*Fagus sylvatica*). Table 1 shows the soil profile discription by genetic horizons.
  Humus form: Mull
  Soil Type: Rendzina

Table 1: Humus- and soil description of plot 1 by horizons according to Englisch & Kilian (1999) and Nestroy et al. (2011)

	Horizon [ÖBS]	Depth [cm]	Texture	Coarse material [%]	Mottles present	Nodules present	Carbonate in fine soil
Humus	L	2,5 – 2	-	-	-	-	-
	Fzo	2 – 0	-	-	-	-	-
Mineral Soil	Ahb	0 – 10	silt	40	n	n	n
	AC	10 – 30	silt	75	n	n	n
	CA1	30 – 45	silt	80	n	n	y
	CA2	45 – 60+	silt	90	n	n	y

- Plot 2 (Plot 29038)
  is situated at an altitude of 566 m a.s.l. on an even, flattened portion of a slope facing southeast at an inclination of 15 %. The base material for the pedogenesis is a colluvium of limestone debris and marl. The soil profile is influenced by stagnant water. The current tree canopy mainly consists of European beech (*Fagus sylvatica*) with intermixed single checker trees (*Sorbus torminalis*) and Scots pines (*Pinus sylvestris*). Table 2 shows the soil profile discription by genetic horizons.
  Humus form: Mull
  Soil Type: pseudovergleyter Kalkbraunlehm

Table 2: Humus- and soil description of plot 2 by horizons according to Englisch & Kilian (1999) and Nestroy et al. (2011)

	Horizon [ÖBS]	Depth [cm]	Texture	Coarse material [%]	Mottles present	Nodules present	Carbonate in fine soil
Humus	L	1– 0	-	-	-	-	-
	F	sparsely	-	-	-	-	-
Mineral Soil	Ahb	0 – 5/10	loam	40	n	n	y
	AB1,gd	5/10 – 30	loamy clay	75	n	y	y
	AB2,gd	30 – 45	loamy clay	80	n	y	y
	BCv,gd	45 – 60+	loamy clay	90	n	y	y

Available Water Storage Capacity

Estimation of the AWSC was done according to AK Standortskartierung (2003) using the following input parameters:

- Density of dry fine soil [g.cm^{-3}]
- Texture class
- Content of organic carbon [%]
- Coarse material content [%]

For the actual calculation, the fine soil density classes were estimated based on expert knowledge, using comparable soil profiles from other projects. Taking density samples using core cutters could raise the accuracy.

The AWSC values were calculated for a depth of 1 m for reasons of comparability by extrapolating the values of the lowest horizon to a depth of 1 m where necessary.

As a result of this procedure we estimated a total AWSC of 61,2 mm m^{-2} for plot 1, and a corresponding value of 126,5 mm m^{-2} for plot 2.

Temperature

The calculation of the mean monthly temperatures for a specific location is based on a spatial interpolation between several neighbouring climate stations using the method of KINDERMANN (2010).

Two climate scenarios assuming an increase in temperature of +3°C and +5°C until 2100 were used encircling the increase of +4°C expected by NIEDERMAIR et al. (2007) in comparison to the last 30 year period, i.e.:

- The period 1981-2010 based on measured values
- The period 2071-2100 with an assumed linear increase in temperature by +3°C between 2000 and 2100
- The period 2071-2100 with an assumed linear increase in temperature by +5°C between 2000 and 2100

From the year 1981 to the year 2012 calculations are based on measured values. From 2013 until 2100 base values are randomly taken from past measurements and a temperature trend is added mathematically to these base values.

Precipitation

Mean monthly precipitation values for the specific locations were derived in an analogous manner according to the interpolation method of KINDERMANN (2010). However, we used the simplifying assumption that the amount of monthly precipitation as well as its annual distribution remain constant in comparison to the last observation period.

Potential Evapotranspiration (PET)

For reasons of the availability of data modelled for a specific position, the Thornthwaite formula (SIEGERT & SCHRÖDTER 1975 after THORNTHWAITE & MATHER 1955 in SCHRÖDTER 1985) was used to calculate the PET using the following input parameters:

- Geographic position
- Monthly mean temperature [°C]

The algorithm implicates that for months with a mean temperature below 0°C the temperature has to be set to 0 as well as the value of PET. This means that in these months no PET is taken into account for the water balance.

Water balance

As starting month for our calculation, March was chosen for the fact that normally full saturation is given at that time and the vegetation period is at its beginning.

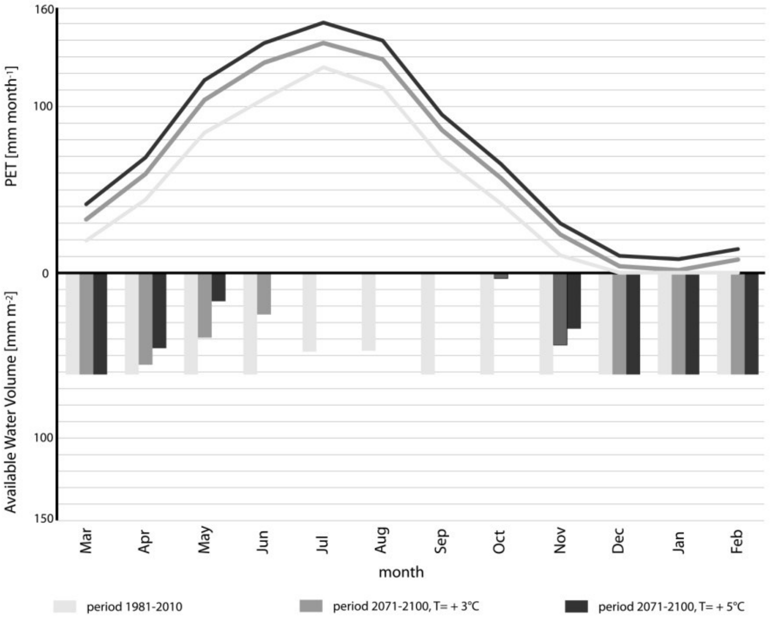

Figure 3: Water balance diagram of plot 1 (Rendzina) for the different scenarios.

Results

The following figures 3 and 4 show the water balance diagrams for the two selected investigation plots 1 and 2.

The upper part of the diagram shows the long term course of the PET in mm per month. The lower part of the diagram shows the corresponding values for plant available water in the soil in mm.m^{-2} for a depth of up to 1m for the 3 given scenarios.

- the period 1981-2010 based on measured values (light grey)
- the scenario 2071-2100 with an assumed increase in temperature by +3°C (dark grey)
- the scenario 2071-2100 with an assumed increase in temperature by +5°C (black)

Conclusions

At both plots - considering all assumptions necessary for the model - it becomes apparent that an increase of already +3°C compared with present climate conditions partly results in a complete depletion of the plant available water reservoir during the summer and autumn months.

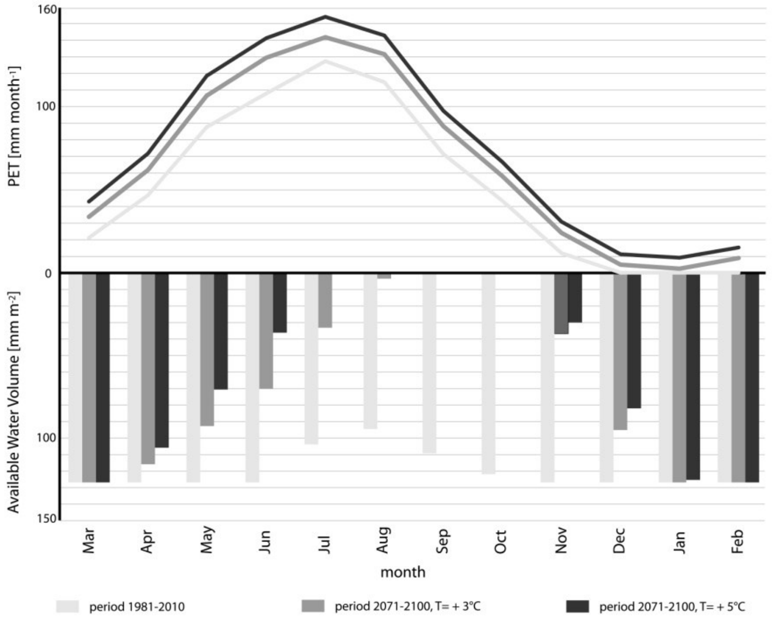

Figure 4: Water balance diagram of plot 2 (Kalkbraunlehm) for the different scenarios.

It becomes clearly visible that - under equal climatic conditions – plot 2 with its higher water storage capacity is able to ensure the water supply for plants at all scenarios for approximately one month more than plot 1.

Comparing the values of AWSC of the two plots with the results found in the German Soil Condition Survey 2006-2009 of Bavaria (KÖLLING & FALK 2010) it has to be stated, that both plots are located in the lowest third of the distribution.

Besides a few, certainly simplified, assumptions for the model it has to be considered that there are factors both enhancing as well as reducing the shown impacts.

Reducing factors

- In fact the absolute plant available water volume per month can be higher than the calculated monthly AWSC values as the precipitation usually is distributed to several separate events repeatedly refilling the storage of plant available water, which in the meantime has been constantly reduced by actual evapotranspiration. Our procedure of balancing based on monthly values treats any amount of precipitation that causes an exceedance of AWSC as to get lost from the system, e.g. by run-off.
- Using the potential instead of actual evapotranspiration displays the effects more drastically than they really are, as plants can individually reduce transpiration to a variable extent. However, this may imply a future shift in vegetation composition towards plants using the available water resources more economically than the present stands.

Enhancing factors

- Even with increasing amounts of precipitation the temperature-induced increasing evapotranspiration remains a problem.
- SCHÖNER et al. (2010) expect an increase of winter precipitation simultaneously coupled with declining summer rainfall already for the period 2012-2050 but especially after the year 2050. Assuming that the annual distribution of precipitation will shift towards the winter half-year the expected impact will be even more drastic than under the present presumptions. So periods showing the highest PET-rates probably will no longer coincide with the precipitation maximum.

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