Department of Forest and Soil Science

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A COMPARISON OF SELECTED SOIL PROPERTIES UNDER HIGH AND COPPICE FOREST IN THE VIENNA WOODS

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Abstract

In this study soil properties of a high forest and a coppice forest in the Vienna Woods were compared. The soil is moderately acidic in the entire research area. 15 soil samples were randomly collected from each forest patch at 80 m interval grid along the plots by means of a soil corer with 70 mm diameter to a maximum soil depth of 60 cm. Soil samples were classified using the FAO- WRB classification system. Each soil profile was divided into ectohumus (O-horizon) as well as into vertical geometric mineral soil horizons of 0 to 5, 5 to 10, 10 to 20, 20 to 40 and 40+ cm depths. Dry mass of ectohumus, coarse and fine mineral soil, of roots, soil bulk density, soil pH, total nitrogen and total and organic carbon of each sample were determined. Statistical analysis revealed differences of ectohumus dry mass, root dry mass, soil bulk density, soil pH, total nitrogen and total and organic carbon at different soil depths under coppice and high forest. As expected, correlation analysis showed that nitrogen and organic carbon are highly positively correlated in high and coppice forest. Ectohumus dry mass in the high forest is significantly higher than in the coppice forest. The soil bulk density increased with soil depth both in the high and coppice forest. The nitrogen content decreased from 18.35 $g.m^{-2}.cm^{-1}$ to 5.46 $g.m^{-2}.cm^{-1}$ with increasing soil depth in the high forest and from 22.43 $g.m^{-2}.cm^{-1}$ to 6.79 $g.m^{-2}.cm^{-1}$ in the coppice forest. The organic carbon content in the high forest decreased from 305.06 $g.m^{-2}.cm^{-1}$ to 53.15 $g.m^{-2}.cm^{-1}$ and in the coppice forest from 381.94 $g.m^{-2}.cm^{-1}$ to 67.93 $g.m^{-2}.cm^{-1}$. The nitrogen and carbon content in the coppice forest is significantly higher than in the high forest in the top 5 cm of soil. Possible reasons are discussed.

Key Words: Coppice forest, high forest, Vienna Woods, soil, dry mass, ectohumus, pH, soil bulk density, nitrogen, carbon, C/N ratio.

Zusammenfassung

In dieser Arbeit werden ausgewählte Bodeneigenschaften von Hochwald- und Niederwaldstandorten im Wienerwald verglichen. Die Böden sind im gesamten Untersuchungsgebiet mäßig sauer. Es wurden jeweils 15 Bodenproben in einem 80 m Raster zufällig verteilt am Hochwald und am Niederwaldstandort genommen. Die Bodenprobenahme wurde mit Hilfe eines Bodenbohrers mit 70 mm Durchmesser durchgeführt, die Probenahmetiefe betrug maximal 60 cm. Die systematische Klassifikation der Bodenprofile erfolgte nach der World Reference Base der FAO-UNESCO. Die Bodenprofile wurden jeweils unterteilt in den Ektohumus (O-Horizont) sowie in vertikale geometrische Mineralbodenhorizonte von 0-5, 5-10, 10-20, 20-40 und 40+ cm Tiefe. Für jede Probe wurden die Trockenmassen von Grob-, Feinboden und Wurzeln, die Lagerungsdichte, die Boden-pH-Werte, Gesamtstickstoff-, Gesamtkohlenstoff- und organischer Kohlenstoffgehalt bestimmt. Statistische Analysen zeigen Unterschiede der Ektohumus-Massen, der Wurzeltrockenmassen, der Lagerungsdichte, der pH-Werte, sowie der Massen von Stickstoff und Kohlenstoff in unterschiedliche Bodentiefen in Abhängigkeit von der Bewirtschaftungsform Hochwald oder Niederwald. Erwartungsgemäß ergab eine Korrelationsanalyse, dass Stickstoff und organischer Kohlenstoff sowohl im Hoch- als auch im Niederwald signifikant positiv korrelieren. Die Ektohumus-Trockenmasse im Hochwald ist deutlich höher als im Niederwald. Die Lagerungsdichte nimmt in beiden Bewirtschaftungsformen bei zunehmender Bodentiefe zu. Die Stickstoffmassen sinken mit der Bodentiefe von 18.35 $g.m^{-2}.cm^{-1}$ auf 5.46 $g.m^{-2}.cm^{-1}$ im Hochwald und von 22.43 $g.m^{-2}.cm^{-1}$auf 6.79 $g.m^{-2}.cm^{-1}$ im Niederwald. Die Kohlenstoffmassen sinken im Hochwald von 305.06 $g.m^{-2}.cm^{-1}$ auf 53.15 $g.m^{-2}.cm^{-1}$, im Niederwald dagegen von 381.94 $g.m^{-2}.cm^{-1}$ auf 67.93 $g.m^{-2}.cm^{-1}$. In den obersten 5 cm des Bodens sind die Stickstoff- und Kohlenstoffgehalte der Böden unter Niederwald bedeutend höher als jener unter Hochwald. Mögliche Gründe dafür werden diskutiert.

Key Words: Niederwald, Hochwald, Wienerwald, Boden, Trockenmasse, Ektohumus, pH-Wert, Lagerungsdichte, Stickstoff, Kohlenstoff, C/N Verhältnis

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1 Introduction

1.1 Research rationale

47.2 % of Austria's federal territories are covered with forests. Forests have at all times contributed to securing people's economic position and they have always been part of the cultivated landscape (Johannes 2004). The Vienna Woods spreads to the west and southwest of the city of Vienna (http://www.biosphaerenparks.at). For a long time it has been a contested space, being claimed for environmental protection efforts and increasing utilisation alike. The Vienna Woods boasts a large-scale forest that is unique for Central Europe. The individual woods are closely interlinked with open areas and special sites and very rich in species. According to a study from 1993 it counts as one of 13 biodiversity centres in Austria (Heilig 2005). The diversity of plants and animals in the Vienna Woods is particularly pronounced along the thermal spring line (http://www.biosphaerenparks.at).

What is a particularly typical feature of Central Europe is the great variety of its landscapes, which offer a multitude of different growth conditions (Johannes 2004). High forest means forest normally composed of trees of seedling origin. Coppice forest refers forest originating mainly from sprouts or root suckers rather than seed (FAO 2005). Vegetation formation composed principally of trees, including shrubs and bush understories, where broadleaved species predominate are called broadleaved forests. Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate are called coniferous forests (FAO 2005). Differences in sites over rather small-scale areas characterise forests in the Vienna woods. In this study we took high and coppice forest within the Vienna Woods to analyze the nitrogen and carbon stores in the soil.

Nitrogen is the predominant nutrient added to forests (Reich and Schoettle 1988). Available and total pools of nitrogen and carbon stores are inherently variable in forest soils (Homann et al. 2001, Conant et al. 2003, Rothe et al. 2002). Since 90% of soil nitrogen reserves are organic, the distributions of nitrogen and carbon usually closely correlated (Lavelle and Spain 2001). Nitrogen deficiencies commonly result in large losses of productivity (Joan and Ramon 1996). According to research in beech stands of the Vienna Woods (Blay 1989), the soil nitrogen content varies considerably among beech stands in the Vienna woods, even though stands were initially selected to be of the same productivity (yield class). Further more he found that the difference in the amount of nitrogen in the living biomass, which was estimated to be 37.2 g N m^{-2} between a 20 year old stand and 120 year old beech stands, only minimally affects the soil nitrogen content. More money and effort have been, and are being, spent on the management of nitrogen than other mineral element (Brady and Weil 2000). Therefore, investigations on nitrogen and carbon stores between high and coppice forest will fill some of the scarce and controversial information gaps in the Vienna Woods.

1.2 Research questions

- Classifying of soil samples in high and coppice forest in the Vienna Woods by international soil classification system
- Determining of humus, vertical decay and soil roots dry mass in high and coppice forest in the Vienna Woods
- Determining of vertical soil pH value in high and coppice forest in the Vienna Woods
- Determining of vertical soil carbon and nitrogen content in the high and coppice forest in the Vienna Woods
- Comparing of soil pH and C/N ratio, nitrogen and carbon content between the high and coppice forest in the Vienna Woods

1.3 Objectives

Studies on soil nitrogen and carbon content in the Vienna Woods contribute to information on following:

- To quantify the humus, roots dry mass, soil bulk density, nitrogen and carbon content in the high and coppice forest in the Vienna Woods
- To compare C/N ratio and pH of the vertical soil profile in high and coppice forest in the Vienna Woods
- To characterise the efficiency of nitrogen and carbon cycle between high and coppice forest in the Vienna Woods
- To identify whether there is a significant relation of nitrogen and carbon distribution across different forest and soil horizons

1.4 Expected results

This study should deliver factual data on soil bulk density, nitrogen and carbon content in the high and coppice forest in the Vienna Woods.

A comparison of nitrogen and carbon content will characterise the difference of soil organic matter stores between high and coppice forest in the Vienna Woods.

A comparison of soil properties between high and coppice forest will help to understand nitrogen and carbon cycle due to different forest management.

2 Literature review

Soil forms a thin mantle over the Earth's surface and acts as the interface between the atmosphere and lithosphere, the outmost shell of the Earth (Bardgett 2005). It is a multiphase system, consisting of mineral material, plant roots, water and gases and organic matter at various stages of decay. Soil formation is stimulated by climate and living organisms acting on parent materials over periods of time and under the modifying influence of topography (Brady and Weil 2000). Soil is composed of 45% minerals, 25% water, 25% air and 5% organic matter. The average concentration of the major elements in the surface of the earth's curst are: SiO_2-67%, Al_2O_3-15.2%, FeO-4%, CaO-3.6%, Na_2O-3.8%, K_2O-2.9%, MgO-2%, TiO_2-0.5%, P_2O_5-0.1%, MnO-0.08% (Taylor and McClennan 1985).

Soil functions in ecosystem are:

- A medium for plant growth: anchors roots, provides nutrients and water
- A hydrologic buffer: regulates water flow in the landscape
- A chemical reactor: absorbs, releases, and transforms inorganic and biochemical compounds (e.g. nutrients, pesticides, minerals, heavy metals)
- A habitat for organisms: micro-organisms are responsible for most chemical transformations, while macro-organisms are responsible for most physical transformations

2.1 Soil properties

Soil properties, which are physical and chemical characteristics, play an important role on the growth of plants. Variation in soil-forming factors determine the physical and chemical nature of soils, which in turn influences greatly the nature of the soil biota and hence ecosystem properties of decomposition and nutrient cycling (Bardgett 2005). In the past, soil chemistry in all its aspects (teaching, research and extension) has been driven by the requirements for improving agricultural and forestry production. There can be little doubt that the well-being of human society, the focus of soil chemistry will increasingly change from agriculture to the environment (Sumner 1998).

2.1.1 Soil texture and structure

Soil texture refers to the relative proportions of various sized particles, which are sand (0.05 to 2.0 mm), silt (0.002 to 0.05 mm) and clay (<0.002mm), within the soil matrix. Soil texture is of important largely because it determines the ability of the soil to retain water and nutrients. Clay minerals have a higher surface area to volume ratio than sand and silt and hence soils with high clay content are better able to hold water by adsorption and to retain cations on their charged surfaces. The ability of a soil to retain cations (e.g. Ca^{2+}, Mg^{2+}, NH_4^+) is refers to as its cation exchange capacity of clay minerals to hold cations on negatively charged surfaces (Bardgett 2005). This retention of cations on clay minerals represents a major short-term store of nutrients for plant and microbial uptake. Texture also influences the distribution of soil organisms and, conversely, may be modified over time through the activities of soil animals (Lavelle and Spain 2001). Brady and Weil (2000) stated that soil texture influences many other soil properties in far-reaching ways as a result of five fundamental phenomena that increase with surface area: water is retained in soils as thin films on the surface of soil particles; both gases and dissolved chemicals are attracted to and adsorbed by mineral particle surface; weathering takes place at the surface of mineral particles, releasing constituent elements including plant nutrients into the soil solution; the surface of mineral particles often carry both negative and some positive electromagnetic changes so that particle surfaces and the water films between then tend to attract each other and stick together in a coherent mass; microorganisms tend to grow on and carry out reactions on particle surfaces. Soil texture has major effects on forest growth, but these effects are indirect (Fisher and Binkley 1999).

Soil structure reflects the binding of the various sized mineral particles into larger aggregates or a ped (Brady and Weil 2000). The actual formation of stable aggregates requires the action of physical, chemical, and biological factors. Kay and Angers (2002) stated that soil structure has a major influence on the ability of soil to support plant growth, cycle C and nutrients, receive, store and transmit water, and to resist soil erosion and the dispersal of chemicals of anthropogenic origin. Soil aggregation and structure is of concern to the soil ecologist, not only because the activity of the soil biota strongly affects it, but also because the structure of soil determines the physical nature of the living space. Bardgett (2005) described that good soil structure is recognized as a key attribute of fertile and biologically active soil, because it increase the flow of water and gases through soil, reducing the possibility of the development of anaerobic conditions which would be detrimental to soil biota and their activities, and harmful to plant growth. Good soil structure promotes free movement of biota, thus increasing opportunities for trophic interactions. It allows roots to proliferate and enables aerobic microbial processes to dominate. Soil aggregation is also influenced by different tree species. Scott (1996) found that the average size of aggregates ranged from 1.5 mm under white pine to 2.1 mm under Norway spruce in an experiment with 35-yare-old plots with different tree species. The influence of tree species on soil aggregation was also apparent from a "lysimeter" experiment in California in which 50 m^3 chambers were filled with soil and planted to Coulter pine or Oak (Graham and Wood 1991).

2.1.2 Soil water

In the soil, water is intimately associated with solid particles. Together with dissolved nutrients they make up the soil solution, an important medium for supplying nutrients and water to growing plants (Bardgett 2005). Or and Wraith (2002) said that changes in soil water content and its energy status affect many soil mechanical properties including strength, compactibility and penetrability, and may cause changes in the bulk density of swelling soils. There are certain water-holding characteristics like potential and hydraulic conductivity of soils that determine the amount of water that is available to plants and soil biota (Fisher and Binkley 1999). Ghilarov (1983) said that the activities of most soil animals are closely circumscribed by soil water status because of their eco-physiological adaptations to a soil-dwelling existence. Water with high free energy tends to move towards a zone of low free energy – from the wet soil to the dry soil and from the upper soil to the lower soil. Soil water potential also affects the activities of microbes. Sommers et al. (1980) demonstrated that carbon dioxide formation (an integrated measure of microbial activity) is reduced by half as soil water potential declines from saturated to – 0.2 MPa. Nitrogen mineralization also declines as soil moisture decline. One study in Kenya found that gross N mineralization dropped from 2.2 to 0.08 μg/g daily as soil water potential fell from – 0.06 to – 5.9 MPa (Fisher and Binkley 1999). In general, the water – holding capacity is greater in soils that contain large amounts of clay or organic matter, because these components have high surface areas that readily retain water. Also clay soils have more pores that readily retain water under gravitational suction than do sandy soil, which have larger pores that are more easily drained (Bardgett 2005).

2.1.3 Soil pH

Soil acidity or pH is a measure of hydrogen ion (H^+) activity in the soil solution and its specially defined as the $\log_{10}$ of the H^+ concentration. In the natural state, the H^+ activity in soil is a function of the parent material, time of weathering, vegetation, climate and topography. In addition to these soil-forming factors, soil pH is influenced by the season of the year, cropping and soil management practices, use of ammoniacal fertilizers, acid precipitation, sludge and manure applications, soil organic matter, and biological activity (Smith and Doran 1996).

A large proportion of the earth's soils are acidic, especially in the tropics, where ecosystems persist at soil pH value of 4 or less. Many northern ecosystems also have very acidic soils. The pH value of the soils in Boreal forests is often of 4 or less. In many parts of the world, soil acidity is further exacerbated by the use of inorganic fertilizers and acid rain (Kennedy 1992). Fisher and Binkley (1999) claimed that in soil where aluminum dominates the exchange complex, pH value range between 4.0 and 4.5 and when the exchange complex is dominated by base cations (e.g. Ca^{2+}, Mg^{2+}, K^+), pH values commonly fall between 5.0 to 6.5, and soil with high carbonate content may have pH value higher than 6.5. Soil becomes acidic if base cations are leached from the soil profile, to be replaced by H^+ and Al^{3+} ions in cation exchange sites. Al^{3+}, Fe^{2+} and Mg^{2+} in soil solution are the major cause of biological harm due soil acidity (Pritchett and Fisher 1987). Bardgett (2005) summarises that acidity in soils can come from various sources:

- Carbonic acid, which is formed by the dissolution of CO_2 in water, dissociated to yield H^+
- Microbial oxidation of ammonium ions (NH_4^+) to nitrate (NO_3^-), the former being derived from mineralization and fertilizer inputs, also yields H^+ ions
- Atmospheric pollution (acid rain) and natural sources of acids, including volcanic eruptions and thunderstorms that yield sulphur dioxides and oxides of N, respectively, produce sulphuric and nitric acids that acidify soils (it has been proposed that the widespread occurrence of acidic soil in tropical and

subtropical regions is, in part, a result of high thunderstorm activity in these region. Long-term weathering and leaching of cations also contributes significantly to acidity in these old soils)

- Decomposition of organic matter that has high concentrations of phenolic and carboxyl groups liberates H^+ ions

It was reported that soil acidity might affect the availability of nitrogen to plant by affecting the activity of microorganisms involved in ammonification, nitrification, denitrification, immobilization and non-symbiotic nitrogen fixation (Robson and Abbott 1989). Marscher (1995) claimed that many of the apparent direct effects of soil acidity on plant growth are actually the result of its indirect effects on such conditions as microbial activities and nutrient availability. If the total concentration of anions in the soil solution increases, the increase in cation concentration will include some extra H^+, and the pH will decrease. This effect of salt concentration is sometimes called the salt effect in the forest soils literature because additions of any salt (such as NaCl or KNO_3^-) will lower the pH of a soil solution even though the solid phase itself has not been altered substantially (Fisher and Binkley 1999). The salt concentration effect is commonly on the order of 0.1 to 0.4 pH unit, with the greatest variations occurring in areas where inputs of sea salt are variable, and in soils where accumulations of nitrate are large. Richter et al. (1988) found that very dilute soil solutions (conductivity of soil solution of 2 mS/m) declined by about 0.3 units in pH when measured in a stronger salt solution (0.01 M $CaCl_2$), whereas soils with higher initial salt concentration (conductivity > 5mS/m) showed no further effect of added salt on pH.

2.1.4 Soil organic matter

Soil organic matter consists of diverse components such as living organisms, slightly altered plant and animal organic residues, and well-decomposed organic residues that vary considerably in their stability and susceptibility to further decomposition (Magdoff 1992). The organic matter content of soil varies tremendously in terms of both its chemical composition and its quantity. This depends on a variety of interacting factors such as vegetation type, climate, parent material, soil drainage, and the activity of soil biota. A particular combination of these factors generally leads to the formation of either mull or more humus

(Bardgett 2005). Soil organic matter has long been considered the key quality factor of soil. Gregorich et al. (1993) described that soil organic matter is a source of and a sink for plant nutrients in soils and is important in maintaining soil tilth, enhancing infiltration of air and water, increasing water retention, reducing erosion, and controlling the efficacy and fate of applied pesticides. Figure 2.1 gives a schematic model of soil organic matter in terrestrial ecosystem.

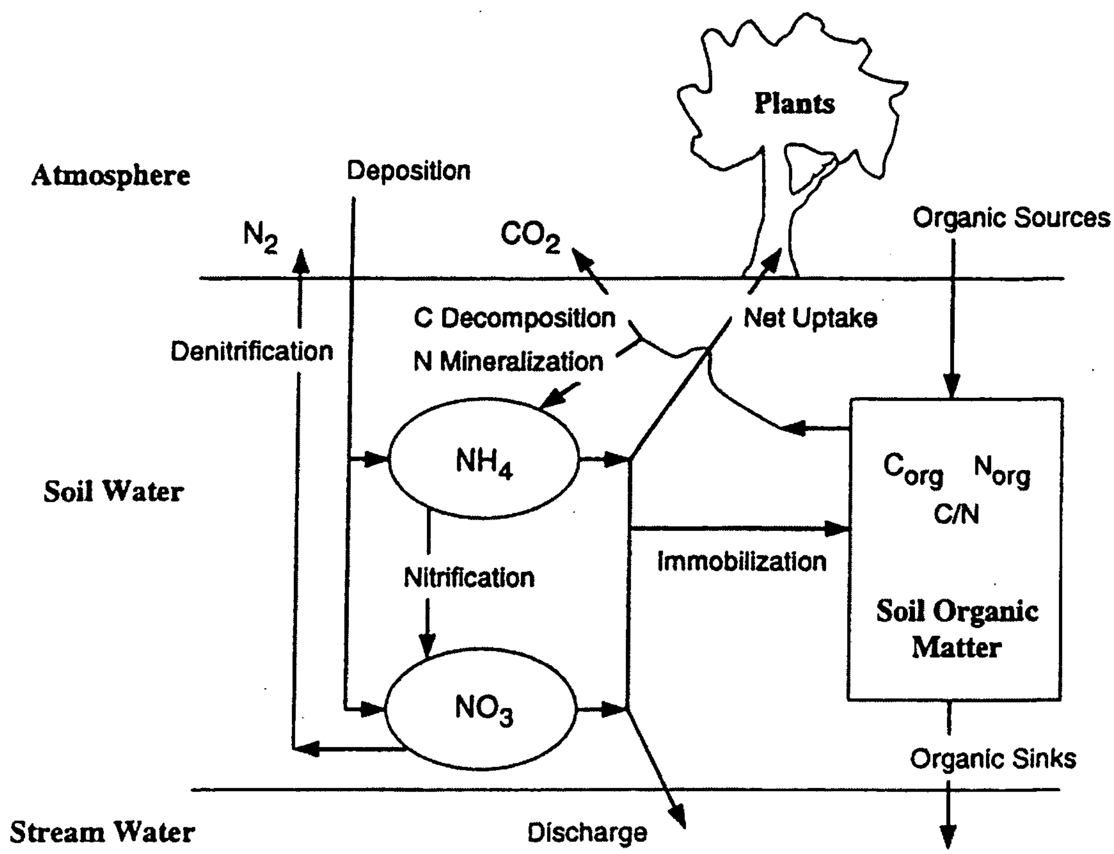


Figure 2.1 Schematic model of soil organic matter in terrestrial ecosystem (http://www.macaulay.ac.uk/recover/images/magic7a.jpg)

Soil organic matter is of particular importance for biota because it is their primary source of nutrients and carbon (Richard 2005). The amount and composition of organic matter in the soil depends on the balance between organic input and rate of decomposition and mineralization (Williams and Woinarski 1997). Soil organic matter is of great scientific interest for two different reasons. The first is its role in maintaining soil productivity (Dyck and Skinner 1990). The second is its role as a source or sink for atmospheric carbon (Johnson 1992). Forest soils are unique in that organic carbon resides both within the mineral soil and on the surface of the mineral soil as organic horizons termed the forest floor (Fisher and Binkley 1999). Michel (2002) found that increasing N inputs to forest ecosystems may result in accumulation of organic matter in forest floors. Bardgett (2005) presented that the rate at which organic inputs to soil are decomposed depends primarily on their quality, which is dependent on the type of compounds that are present within them. Rapidly decomposing material, such as the litter of deciduous trees and animal faeces, generally contain high amounts of labile substances, such as amino acids and sugars, and low concentrations of recalcitrant compounds such as lignin. In contrast, the litter of coniferous trees decomposes slowly, being rich in large, complex structural compounds such as lignin and defence compounds such as polyphenols. This material is also unpalatable to soil fauna, further slowing down its decomposition. The importance of variation in the rate of decomposition at the ecosystem scale relates to the production of CO_2 from heterotrophic microbial activity and its evolution into the atmosphere, and to the conversion of organic nutrient forms to simple inorganic nutrients that are available for plant uptake, a strong determinant of plant productivity (Bardgett 2005). An increased mobilization of dissolved organic carbon might contribute to the accumulation of organic matter because it appears to be a precursor of stable soil organic matter (Michel 2002).

2.2 Nitrogen and carbon in terrestrial ecosystem

Recent advances in biologically based ecosystem models of the coupled terrestrial, hydrological, carbon, and nutrient cycles have provided new perspectives on the terrestrial biosphere's behaviour globally, over a range of time scales (Schimel et al. 1997). Knops and Tilman (2000) demonstrated that the rate of carbon accumulation was controlled by the rate of nitrogen accumulation, which in turn depended on atmospheric nitrogen deposition and symbiotic nitrogen fixation by legumes. There is not much data available on the effects of N fertilization and ecosystem C storage under climate change, but it has been suggested that ecosystem that are subject to high N loads could act as localized sinks for CO_2, as a result of increase in primary productivity and therefore C sequestration (Lloyd 1999).

2.2.1 Nitrogen

Nitrogen is a major component of all amino acids, which are the building blocks of proteins. It is the dominant element in the atmosphere where it occurs principally as dinitrogen gas. The primary sources of N for terrestrial ecosystems are ammonium and nitrate ion dissolved in rainfall and biological N fixation by microorganisms (Binkley 1986). Post-industrial human activities have increased substantially the release of reactive N into the global environment. The increase in N has resulted from a range of human activities, including the fixing of N_2 for fertilizers, the burning of fossil fuels, increasing use of legumes in agriculture, and mobilization of N from long-term biological stores, such as forest and wetlands. Most natural and semi-natural plant communities are N limited, so the addition of N will substantially alter their structure and productivity, favouring productive, fast-growing species that are best able to use this added resource (Bardgett 2005).

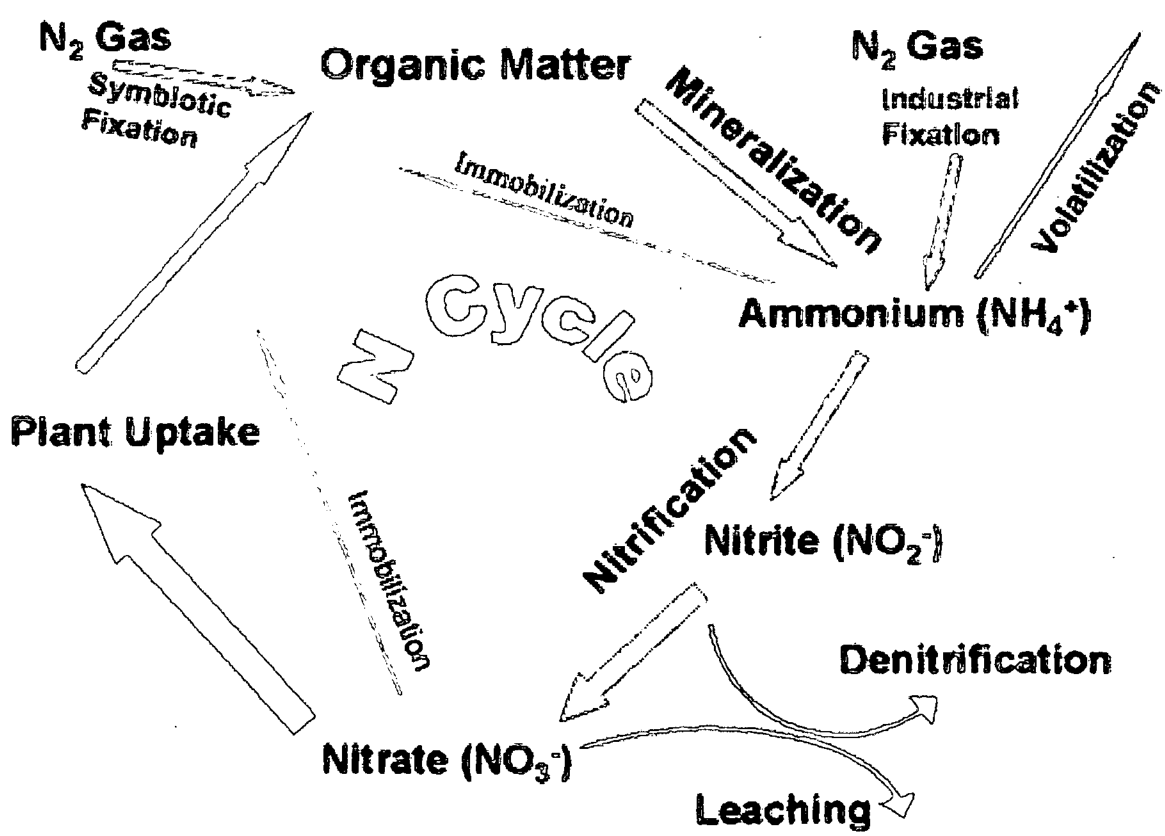


Figure 2.2 Simplified soil nitrogen cycle (http://www.ipm.iastate.edu/ipm/icm/2001/10-22-2001/50degreesfig1.gif)

Nitrogen cycle and transformation in terrestrial ecosystem include the following process: fixation, mineralization, ammonification, nitrification, immobilization, plant uptake, leaching, volatilization, and denitrification. Figure 2.2 simplifies the soil nitrogen cycle.

For a variety reasons, nitrogen cycle has received more attention in forest research than any other nutrient. Nitrogen availability limits growth in more forests in more regions than any other nutrients, and it can be important even when not limiting, because substantial leaching of nitrate N can occur when nitrogen availability exceeds plant uptake (Binkley 1986). Nitrogen leaching is undesirable for several reasons. The N is lost from the site, and the nitrate anion is also accompanied by cation nutrients, such as K^+ and Ca^{2+}. This sequence also generates H^+ and may acidify the soil. At high concentrations nitrate may be toxic in drinking water. The addition of major oxidation and reduction processes makes the N cycle more complex. There are six major processes in the overall cycle.

A. Nitrogen fixation uses energy derived from photosynthesis to reduce atmospheric nitrogen to ammonia which can be then be used and recycled within the ecosystem;

$$N_2 + 8H^+ + 8e^- \longrightarrow 2NH_3 + H_2$$

The gain of electrons by the N atoms indicated this is a reduction step that consumes energy.

B. Ammonium assimilation follows nitrogen fixation or ammonium uptake. Ammonia is aminated (after the removal of H^+ in the case of ammonium) onto an organic molecule such as glutamate to produce glutamine:

$$(CH_2)_2(COOH)_2CHNH_2 + NH_3 \longrightarrow (CH_2)_2(COOH)_2CH(NH_2)_2 + H_2O$$

Various other N compounds are then produced by "transamination".

C. Ammonification is the release of ammonia from decomposing organic matter (such as glycine):

$$CH_2NH_2COOH + 1.5\ O_2 \longrightarrow CO_2 + H_2O + NH_3$$

At pH levels common in soils, the ammonia immediately absorbs one H^+ from the soil solution to become ammonium $NH4^+$.

D. Nitrification is the microbial oxidation of ammonium to form nitrate:

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$$

Electrons are donated from the N atom to the oxygen molecule, releasing energy for use by the microbes. Both nitrate and ammonium may be used as N sources for protein formation.

E. Nitrate reduction to form ammonia must precede use of nitrate by plants and microbes:

$$NO_3^- + 9H^+ + 8e^- \longrightarrow NH_3 + 3H_2O$$

As with N fixation, this is a reduction reaction that consumes energy.

F. Denitrification is also a form of nitrate reduction, but in this case the nitrate anion is used as terminal electron acceptor in the absence of oxygen. Nitrate is reduced to N_2 (or in some cases N_2O) and lost from the ecosystem:

$$2NO_3^- + 12H^+ + 10e^- \longrightarrow N_2 + 6\,H_2O$$

This process is driven by the domination of electrons from highly reduced carbon compounds.

Nitrogen is a key element controlling species composition, diversity and productivity of many terrestrial ecosystems (Vitousek et al. 1997). It is found that in soil mainly within the organic matter fraction where it occurs largely in humic compounds but also in plant roots, the microbial biomass and in decomposing organic materials (Lavelle and Spain 2001). Fog (1988) assumed that high amounts of available N suppress the degradation of lignin in forest ecosystem and Michel (2002) described that incomplete decomposition of lignin might favour the formation of water-soluble products and hence the release of dissolved organic carbon. Blazier et al. (2006) described that low crop tree N accumulation can contribute to losses of applied N via leaching, surface runoff, ammonia volatilization, or denitrification. A deficiency of

N may be caused by either fixation of N or by soluble and readily accessible carbon sources increasing microbial competition for the N source (Park 1975).

2.2.2 Carbon

While not a nutrient element, carbon is a major component of the tissues of all organisms and is one of the elements closely associated with life. It is the vehicle for biological energy transfer within the biosphere at landscape and ecosystem scales, and within organisms (Lavelle and Spain 2001). The modern global carbon cycle of principal carbon pool and exchanges between them shows two significant fluxes: between atmosphere and the land plants; between atmosphere and the ocean (Minjigmaa 2005). The release (natural and anthropogenic) and sequestration of carbon has gained increasing interest in recent years due to its potential impact on global climate. Rosenberg et al. (1999) said that soil plays a key role in the global carbon balance because it supports all terrestrial ecosystems that cycle much of the atmospheric and terrestrial carbon. The estimated amount of carbon stored in world soils is about 1100 to 1600 Pg, more than twice the carbon in living vegetation (560 Pg) or in the atmosphere (750 Pg). Hence, even relatively small changes in soil carbon storage per unit area could have a significant impact on the global carbon balance (Kimble et al. 2006). The amount of carbon soils can retain is dependent on several factors. Inherent factors include climate variables (temperature and rainfall) and clay content.

Singh et al. (1995) stated that the soil carbon of an ecosystem is determined by the quality and quantity of biomass additions and its loss through decomposition. The role of carbon accumulation or loss from soil is determined by the quantity of recyclable biomass-carbon, temperature, rainfall, soil moisture content and disturbances. There are two types of carbon pools in the pedosphere: soil organic carbon (SOC) and soil inorganic carbon (SIC). Table 2.1 gives an estimate of soil organic carbon and inorganic carbon pools in world soils.

The soil organic concentration ranges from low in soils of the arid regions to high in soils of the temperate regions, and extremely high in organic or peat soil. Table 2.2 shows Soil organic carbon pool in terrestrial ecosystem.

Table 2.1 Estimate of soil organic carbon and inorganic carbon pools in world soils (Eswaran et al. 1995)

Carbon pools to 1 meter depth in Pg		
Soils	organic	inorganic
Ultisols	101	0
Andislos	69	1
Aridisols	110	1044
Oxisols	150	0
Inceptisols	267	258
Alfisols	136	127
Mollisols	72	139
Vertislos	38	25
Spodosols	98	0
Entislols	106	117
Histosols	390	0
Miscellaneous	18	0
Total	1555	1738

Table 2.2 Soil organic carbon pool in terrestrial ecosystem (Prentice 2001)

Ecosystem	Area (109 ha)	SOC pool (billion tons C)	SOC density (tons C. ha-1)
Tropical areas	1,76	213 – 216	121 – 123
Temperate forest	1,04	100 – 153	96 – 147
Boreal forest	1,37	338 – 471	247 – 344
Tropical savannas and grasslands	2,25	247 – 264	110 – 117
Temperate grasslands and scrub land	1,25	176 – 295	141 – 236
Tundra	0,95	115 – 121	121 – 127
Desert and semi – desert	4,55	159 – 191	35 – 42
Crop land	1,60	128 – 165	80 – 103
Wetlands	0,35	225	643

Managing soils for carbon provides additional benefits. The benefits of increasing soil organic carbon include increased plant productivity and enhanced soil, water, and air quality. Neff and Asner (2001) presented that studies of dissolved organic carbon fluxes have centered on temperate forest soils, but fluxes of soluble carbon through surface soils should be an important component of internal ecosystem carbon cycling even in systems with low net hydrologic export of dissolved organic carbon. Figure 2.3 simplifies the relationship among soil organic carbon and apart of environmental elements.

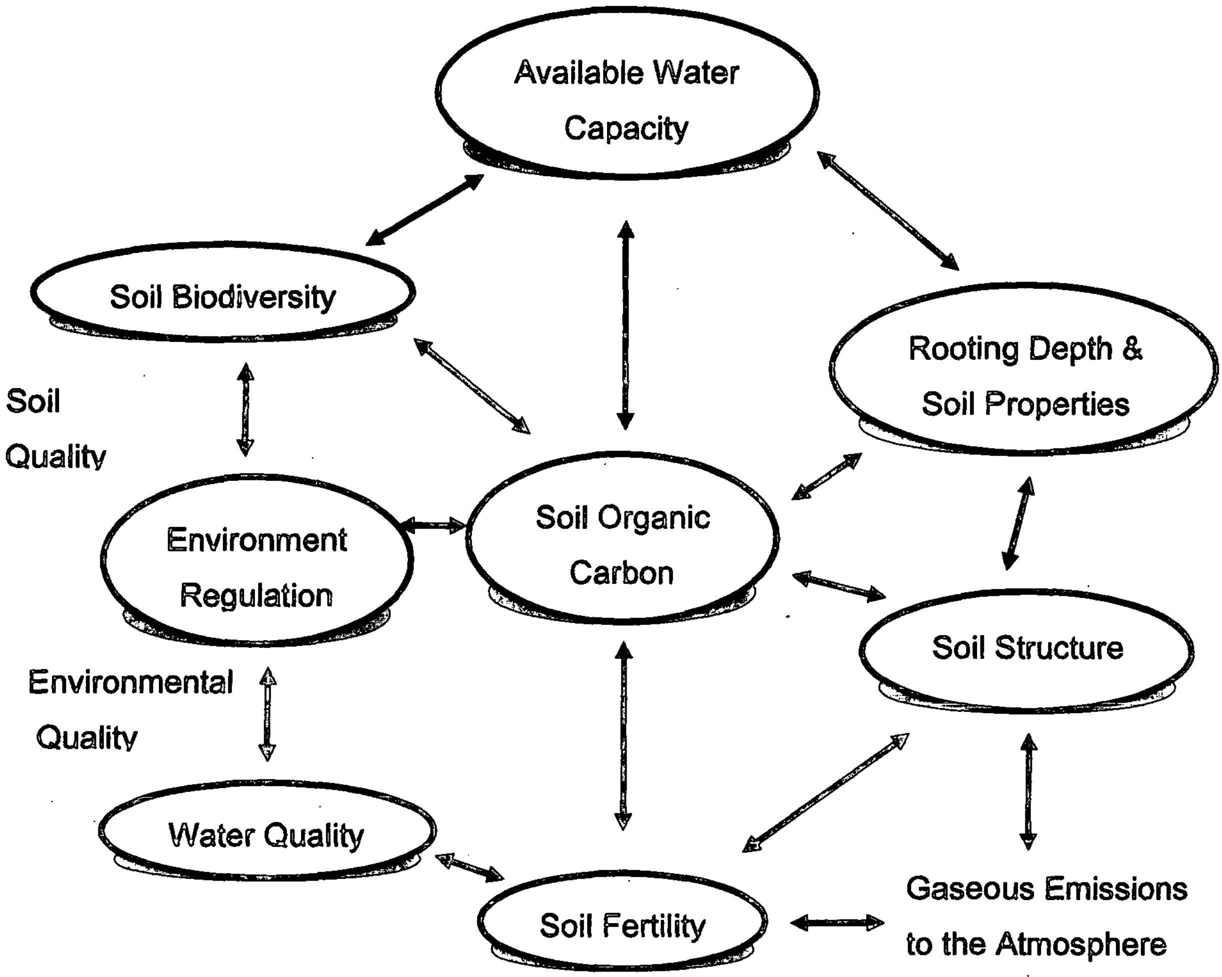


Figure 2.3 Relationship among soil organic carbon and apart of environmental elements

The soil inorganic carbon pool consists of primary inorganic carbonates or lithogenic inorganic carbonates, and secondary inorganic carbonates or pedogenic inorganic carbonates. Secondary carbonates are formed through dissolution of primary carbonates and re-precipitation of weathering products (Sahrawat 2003). Despite the dominant role that calcium carbonate plays in modifying the physical, chemical and biological properties and behavior of plant nutrients in the soil, its role in carbon sequestration in calcareous soils is not well researched. The role of soil inorganic carbon is important for sequestering carbon, but the mechanisms involved are not well understood (Sahrawat 2003). Reconstruction of carbonate fluxes in soil formed in strongly calcareous parent material over geological time periods suggests that this mechanism could account for upward of 1 Mg ha^{-1} yr^{-1} of soil inorganic carbon. These results provide definitive estimates of contribution that soil inorganic carbon can make to carbon sequestration in calcareous soils (Izaurralde 2001).

2.2.3 C/N ratio

The ratios of carbon to other nutrient elements in decomposition tissues have a controlling influence on their breakdown and on the recycling of their nutrient elements. In particular, the ratio of carbon to nitrogen, which represents the relative proportion of the two elements, has been widely used as an index of tissue decomposability and of the capacity of carious materials to supply nitrogen to higher plants and to microorganisms (Lavelle and Spain 2001). There is always more carbon than nitrogen in organic matter.

The C/N ratio is important because of what happens when organic matter is incorporated into soils. The C/N ratio of soil organic matter affects microbial activity, microbial use of inorganic N, release of residue N, and overall N availability to plants. Heterotrophic microorganisms decomposing plant tissues in terrestrial environments normally have to cope with materials with high C/N ratio than those of their own tissues. Nitrogen deficiencies may limit the productivities of both microorganisms and plants, depending on the nature of the decomposing materials and their stage on decomposition. Stevenson (1986) considered that net mineralization leading to an increase in inorganic nitrogen will occur below a C/N ration of 20, an approximate equilibrium state will pertain between 20 and 30 and that over 30, net immobilisation will take place constraining the supply of nitrogen to plants.

Batjes (1996) stated that in undisturbed, fully-developed soils and those at approximate equilibrium with their management regimes, C/N ratio are relatively constant, although clear differences exist between environments and soil taxonomic groupings at a rang of scales. Garte et al. (1994) 's analysis indicates that observed topographic differences in soil N transformations are related to differences in leaf litter quality, stand composition, and soil C/N ratios. They also found the direct effect of soil moisture on microbial processes and the transport of nutrients from ridges to the valley floors certainly both contribute to the ability of the index to predict N concentrations and C/N ratios in soil. Spain et al. (1983) analysed the C/N ration of the A1 horizons of more than three thousand Australian soils and the data for three selected are presented in Table 2.3. As shown, few consistent differences were apparent between temperate and tropical climate soils. Post et al. (1985) stated that soils of hot humid climates tend to have lower C/N ratio than cold areas. Differences between vegetation types also exit and cultivated lands tend to have lower C/N ration than forests (Attiwill et al. 1993).

Table 2.3 C/N ratio of the A1 horizon of soils from three regions of Australia (Spain et al. 1983)

Area	media	Inter-quartile range	sample size
Tropical areas	16	13 – 20	783
Tasmania (cool temperature)	16	13 – 22	142
West Australia (Temperature)	21	16 – 29	162

In some soils, C/N ratio may decline with increasing soil depth because of the greater amounts of fixed NH_4^+ at depth (Lavelle and Spain 2001). Slight decreases occur with depth in many soils reflecting the greater humification greater age of the organic carbon stored deeper in the profile (Batjes 1996). Michel (2002) considered soil respiration decreased significantly with decreasing C/N ration and increasing N content. He also stated that humification indices of dissolved organic matter leached from Oa material characterized by wide C/N ratios were higher compared to soil organic matter with low C/N ratios indicating a higher degree of humification.

3 Materials and methods

3.1 Study site- the Vienna Woods

3.1.1 Profile of the Vienna Woods

The Vienna Woods is located in west and southwest of the city of Vienna. It is a low, wooded section of the Alps in eastern Lower Austria and Vienna, covering over 1,000 squares kilometres and including the northernmost parts of the entire Alpine chain. The Vienna Woods may be defined as that group of hills bounded by the rivers Triesting, Gölsen, Traisen and Danube, and is a favourite outdoor destination for the densely populated area around Vienna. The area has been protected under environmental law since the 19th century and is heavily forested whilst still displaying considerable diversity of land use (Kressler and Kim 2000). Absolute elevation of the territory ranges is from 160 to 893 meters (http://www.biosphaerenparks.at). Figure 3.1 shows the map of the research area.

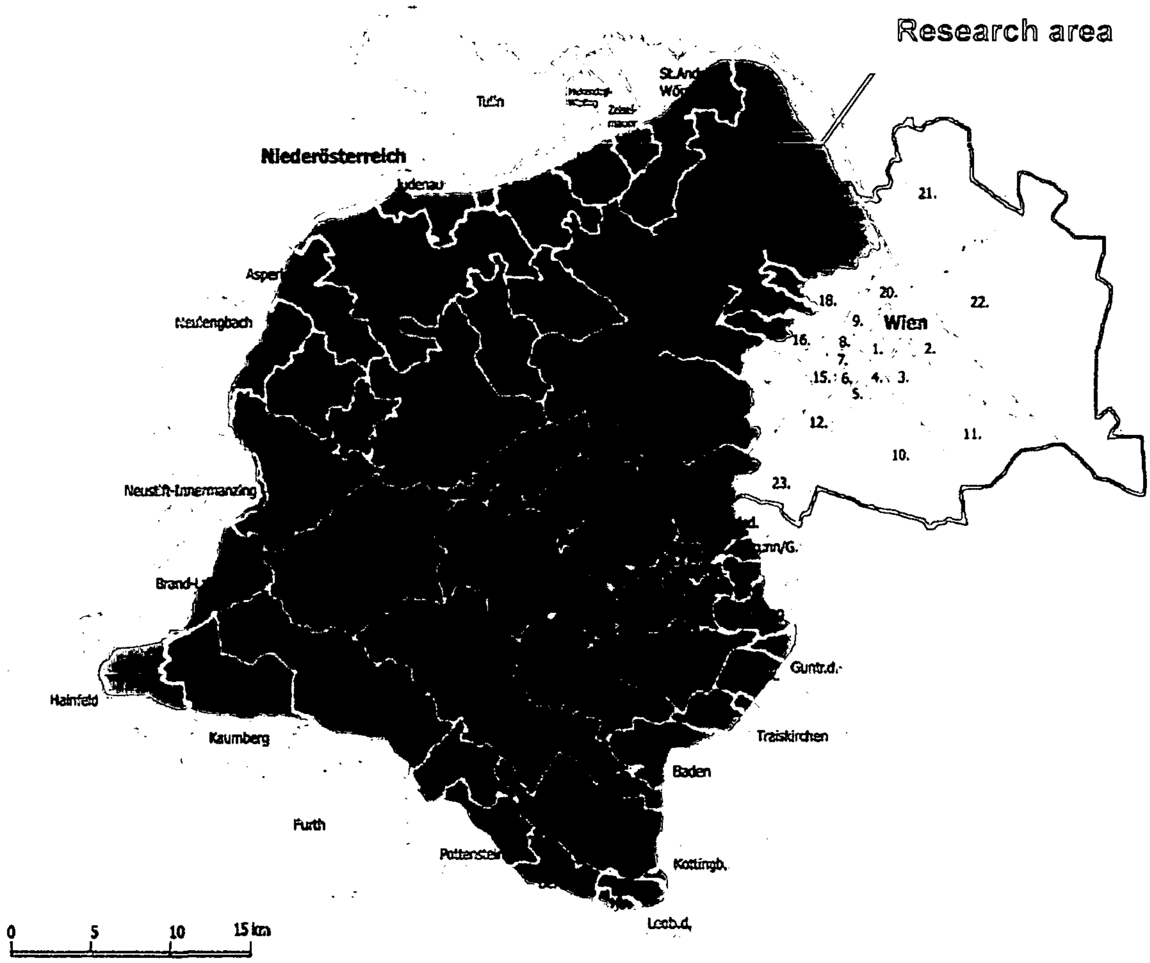


Figure 3.1 Map of the Vienna Woods (http://www.biosphaerenparks.at)

3.1.2 Site location

The investigated area lies around longitudes 16°14'01" and latitudes 48°13'19'. Figure 3.2 shows the study area. It extends 500 m from east to west and 600 m from north to south. The elevation is between 300 to 420 m above sea level. The area is drained in the North by the Weidlingbach which empties into the Danube River, and in the West by the Mauerbach which flows into the Wien River (Blay 1989).

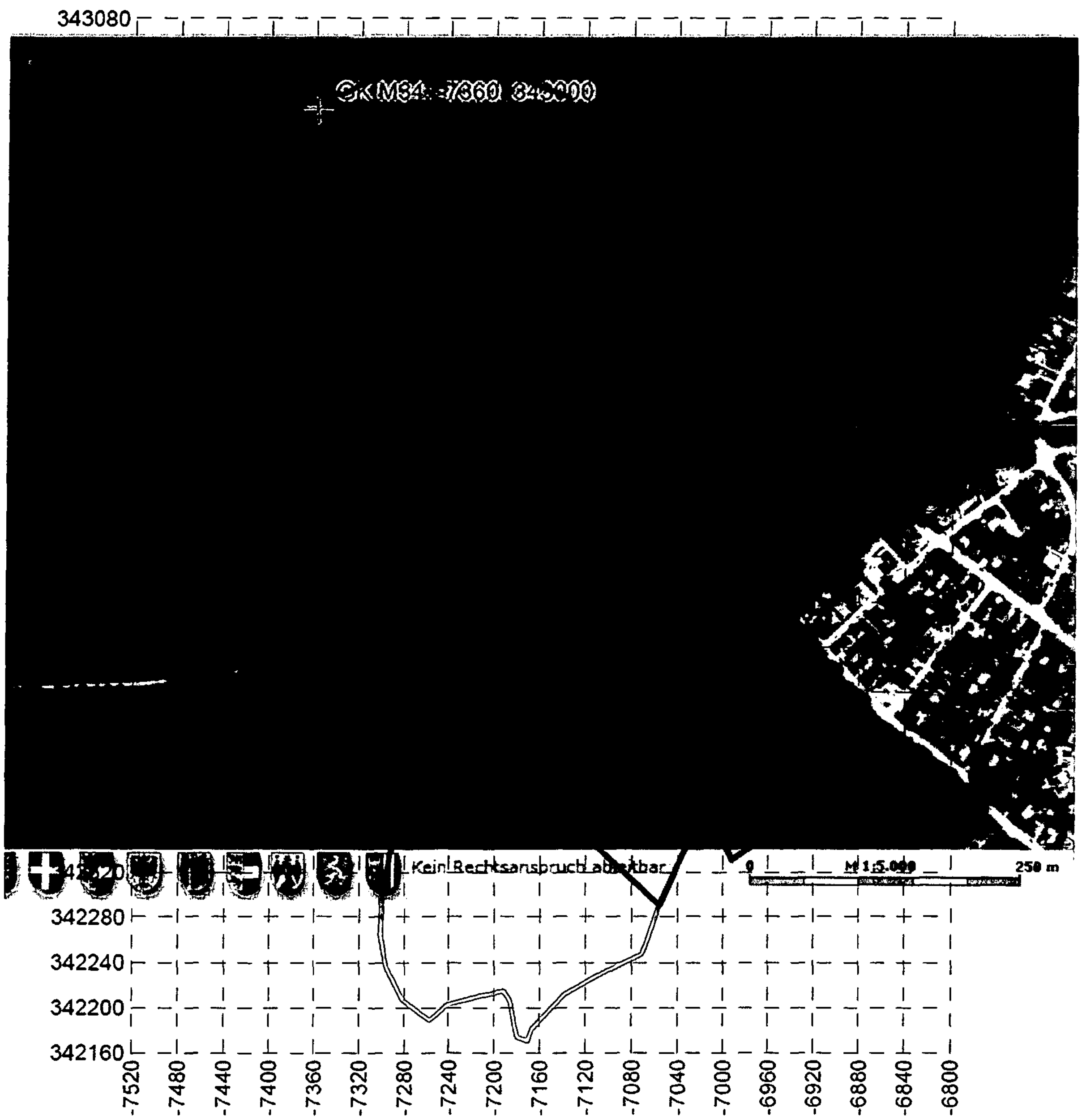


Figure 3.2 Map of the study area

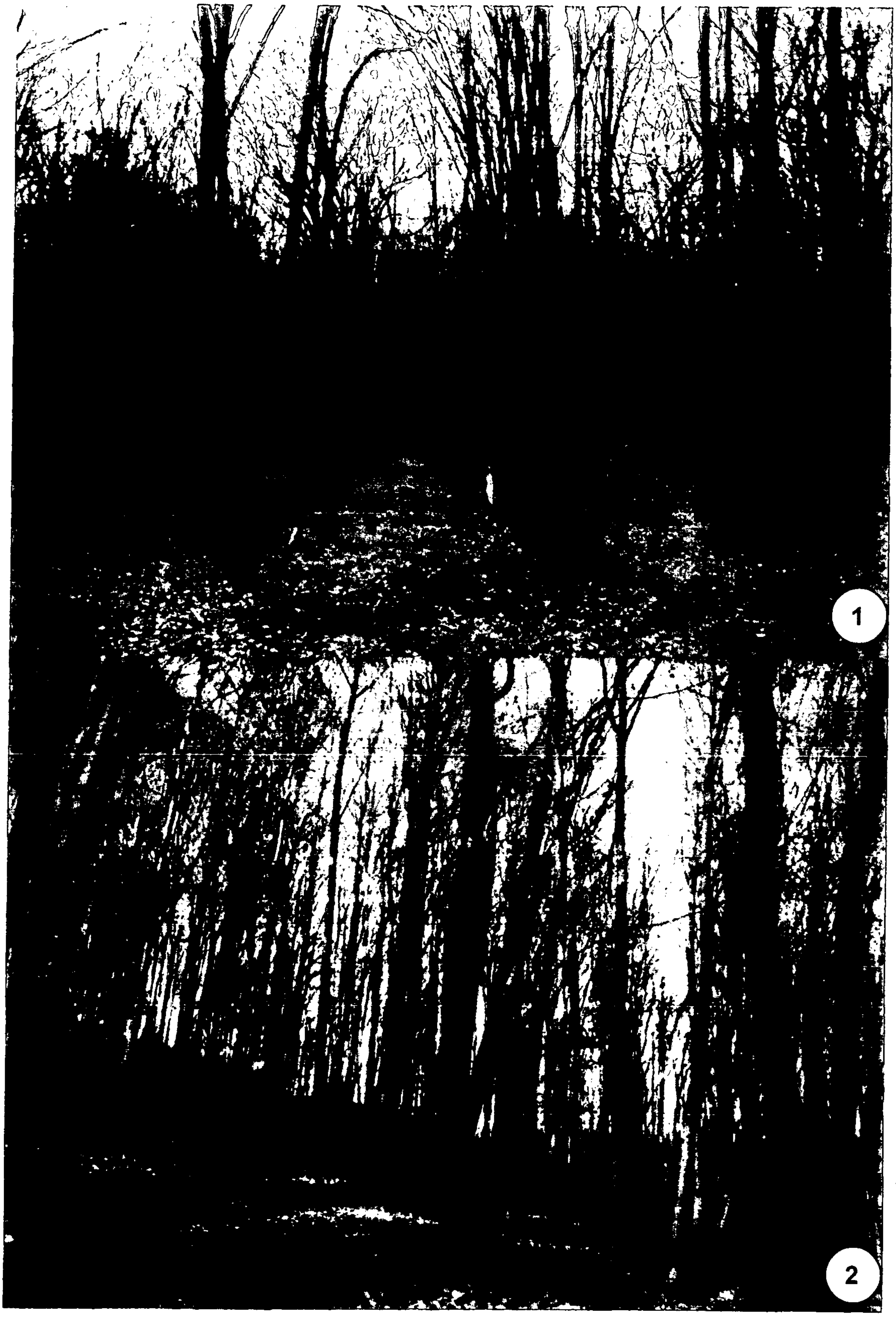


Figure 3.3 Landscape of soil sampling area (1. Coppice forest; 2. High forest)

Figure 3.3 shows the profile of coppice forest and high forest.

3.1.3 Geology and Geomorphology

Geologically, the Vienna Woods is divided into two parts. According to the bedrock it can be split into the limestone Vienna Woods and the sandstone Vienna Woods. The border between the two quite distinct landscapes is a line running from Altenmarkt to Alland - Kaltenleutgeben - Kalksburg - Mauer. The Vienna basin forms its eastern border, in the south it is edged by the Triestingtal and Gölsental valleys, in the west by the river Große Tulln and in the north by the plain of the Tullnerfeld and the Danube. The Vienna Woods is a transitional space. It is here that the easternmost spurs of the northern limestone Alps peter out into the Vienna basin (http://www.biosphaerenparks.at/biosphaerenparks/bsr/englisch/wienerwald/wiener wald_geology.html).

3.1.4 Climate

The Vienna Woods is two-partite not only in geological but also in climatic terms. It lies in the transitional area between a predominantly Atlantic west and the Pannonic climate in the east. The ridges run from southwest to northeast and act as a weather and climate shed. On average the humid, mild west gets 1000mm precipitation per year, while the eastern part is drier with 600mm precipitation a year and the summers are warmer (http://www.biosphaerenparks.at).

3.1.5 Ecosystem and vegetation

In the limestone Vienna Woods the fragrant Sweet Woodruff (Galium odoratum) grows beneath the beeches. Due to lack of light under the dense canopy few other herbaceous plants thrive there. The flysh Vienna Woods, on the other hand, is dominated by forests of oak and hornbeam, to be followed by beech with a *Carex pilosa* understorey at higher altitudes. The ash forests in the peak region of north-facing slopes are a special feature of this area. Typical for the central part of the Vienna Woods are large meadows. Here one can still find extensively farmed open land, mainly seasonally flooded brome grass and rye-grass meadows as well as rich wet meadows in the valleys. Along the many watercourses there are remnants of riparian forests of predominantly ash and black alder.

Beech (*Fagus sylvatica*) and Oak (*Quercus robur*) are dominated in the high forest in the research area. The stand age is around 80 years old. The coppice forest is an un-even forest stand of age between 30-80 years old and is dominated by Turkey Oak (*Quercus cerris*) and Hornbeam (*Carpinus betulus*).

3.1.6 Soils

In terms of soil texture, soil type is characterized by interaction between climate, basic geological material, relief and vegetation. Blay (1989) reported that three soil types are distributed in the research area.

- Pseudogley: wet forest soil, pale-grey colour with brown rust spots and up to pea-large pellets from iron and manganese minerals. The layers frequently produce primary Pseudogley which impedes vertical water movement into the subsoil.
- Braunerde: frequent soil types of the humid climate with the horizon succession Ah/Bv/C are moderate.
- Parabraunerde: characterised by its mechanical clay sludging and shirts of limonitic iron.

3.1.7 Soil classification

We classified soil samples by international soil classification (units of the FAO – UNESCO – ISRIC world soil Mapping). 15 soil profiles from each forest were identified by using USDA soil color Munsell chart 1977 edition. Those soil profiles are characterized and described in term of soil depth, texture, drainage, color, erosion status, stoniness or rockiness and surface sealing based on the guide line developed by FAO – UNESCO – ISRIC.

Soil profile description was made by Ass Prof. Dr. Monika Sieghardt (UNI-BOKU, Institute of Forest Ecology) and Dipl-Ing. Viktor Bruckman (Austria Academy of Sciences). Photographing was made by Viktor Bruckman. Figure 3.4 shows some soil profiles from the research area.

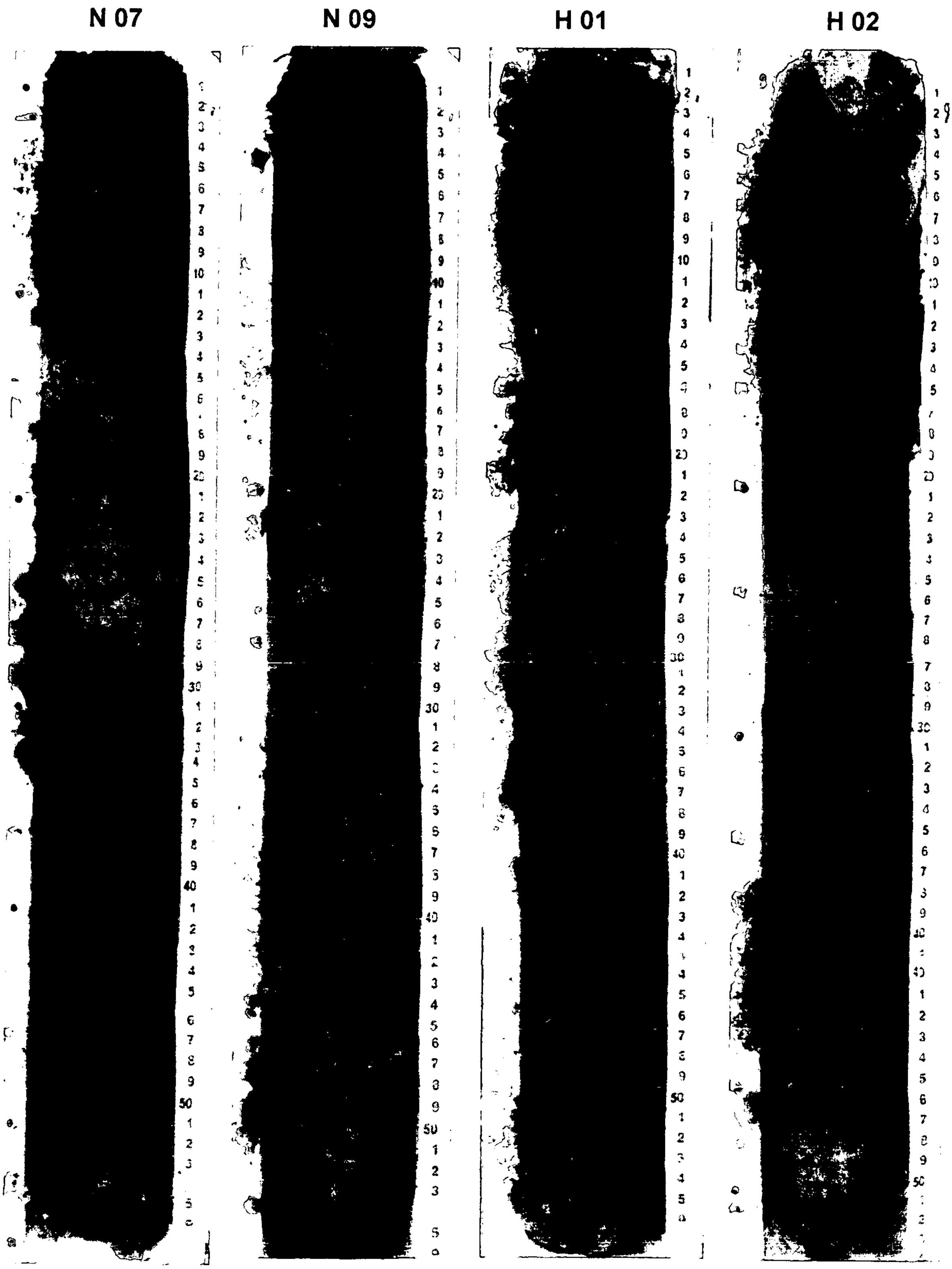


Figure 3.4 Soil profiles (N 07, N 09 from coppice forest; H 01, H 02 from high forest)

3.2 Study design

We intended to obtain basic soil property data for the high forest and coppice forest in the Vienna Woods. This study was conducted at the high forest extended 400 m from south to north and 280 m from west to east and coppice forest extended 400 m from south to north and 360 m from west to east. Random sampling was made in the study areas as the following scheme.

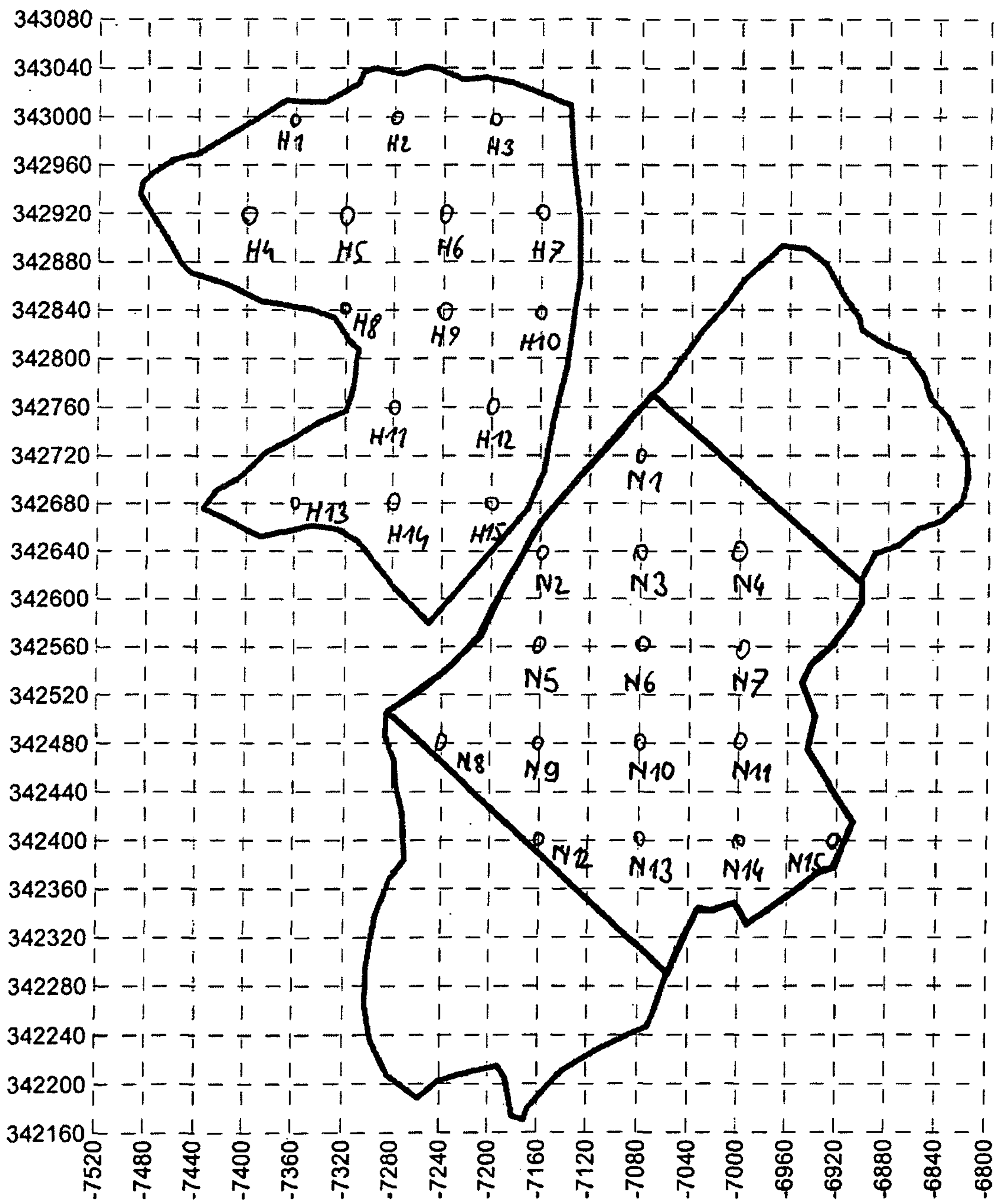


Figure 3.5 Schematic location of the study area

3.3 Soil sampling and laboratory procedure

3.3.1 Soil sampling collection

Soil samples were collected from two forest patches, 15 samples from each patch. Soil sampling was at 80 m intervals along the plots by means of a 70 mm soil corer to a depth of 60 cm. All the soil samples were stored in the green house after sampling collection from the research area in November 2006.

3.3.2 Laboratory procedures

I started the laboratory work at the beginning of February 2007. First of all, I demarcated the Zero-Line between ectohumus and mineral soil, distinguished the total depth of the soil profile and marked the respective geometric soil horizon: 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, 20 to 40 cm, 40+cm. Starting at the end of soil profile, I sorted out living roots and determined the total fresh weight of the respective horizon. And then I dry sieved of the soil horizon in 2 mm size standard mesh sieve without destroying the sandstones. Afterwards I wet sieved of the stones, dried stones at the same sieve and determined the dry weight of stone. The fresh weight of fine soil equals the total fresh weight of the respective soil horizon minus dry weight of stones. Every sample should be given internal sample numbers according to the lab system. 20 g of fresh fine soil was exactly weighed in a paper bag and determined the dry mass after drying it up to constant weight at 105 ° C. A volume spoon of 2.5 ml was used to fill two vessels for suspending samples in H_2O deionized and 0.01 *M* $CaCl_2$ solution for pH determination. The rest of the fine soil was filled into a paper beaker, determined the weight and air dried to constant weight. The ectohumus was filled in a paper bag with the respective lab sample number and dried at 105 °C to constant weight and the dry mass is determined.

3.3.3 Chemical analysis

Soil chemical parameters were determined by standard procedures. For GLP fitted certified soil samples (BCR) were treated in a similar way as the analytic samples.

Soil pH was determined in 1:3 soil suspensions in deionized H_2O (for active acidity) and 0.01 M $CaCl_2$ (for potential acidity) using potentiometer pH – meter (ÖNORML 1083).

Total nitrogen was determined by Semi-micro-Kjeldahl analysis. Wet combustion of air-dry soil samples was carried out with H_2SO_4 (98%) and catalyst containing K_2SO_4 and $CuSO_4$ at 400 °C. Automatic vapor distillation with saturated NaOH and titration of evolved NH_3 using a Kjeltec Auto 2300, (TECATOR) with automatic calculation device was used (ÖNORML 1082).

Total carbon was determined by C/S-Element Analyzer LECO S/C 444 using oven dried samples. Dry combustion at 1400 °C in pure O_2 atmosphere and infrared detection of evolved CO_2 was applied (ÖNORML 1080).

3.4 Statistical data procedures

In order to detect significant influences of different forest and soil depth on ectohumus biomass, root biomass, soil bulk density, pH value, nitrogen, carbon and C/N ration, their calculated mean values were compared using Excel and SPSS version 12.0.1 for windows. To test whether there exit a significant difference in the humus biomass, pH values, nitrogen and carbon content between different forest and among the five horizons, one way ANOVA and T test were conducted.

4 Results

4.1 Ectohumus dry mass

Ectohumus from each soil sample in the high and coppice forest was collected upper the zero line and determined the dry mass (Table 4.1) after drying it up to constant weight at 105 ° C.

Table 4.1 Dry mass ($g.m^{-2}$) of the ectohumus (O-horizon) in the high and coppice forest in the Vienna Woods

Coppice forest patch		High forest patch	
Profile No.	Dry mass (g.m-2)	Profile No.	Dry mass (g.m-2)
N1	3237	H1	2569
N2	1305	H2	3073
N3	1043	H3	2116
N4	1092	H4	4802
N5	658	H5	2745
N6	3294	H6	5101
N7	1383	H7	2366
N8	1581	H8	4183
N9	1781	H9	2532
N10	2218	H10	4934
N11	1947	H11	5275
N12	1955	H12	4045
N13	1617	H13	3252
N14	871	H14	5821
N15	1253	H15	5766

Generally, the high forest has a higher humus deposition than the coppice forest as the Figure 4.1 shows.

A simple T-test (Table 4.2) shows significant differences between the high and coppice forest in the research area. The mean dry mass value of the ectohumus is 1682 $g.m^{-2}$ in the coppice forest and 3905 $g.m^{-2}$ in the high forest. In a 95% confidence interval, the ectohumus dry mass is from 1255 to 2110 $g.m^{-2}$ in the coppice forest and from 3179 to 4172 $g.m^{-2}$ in the high forest in the research area.

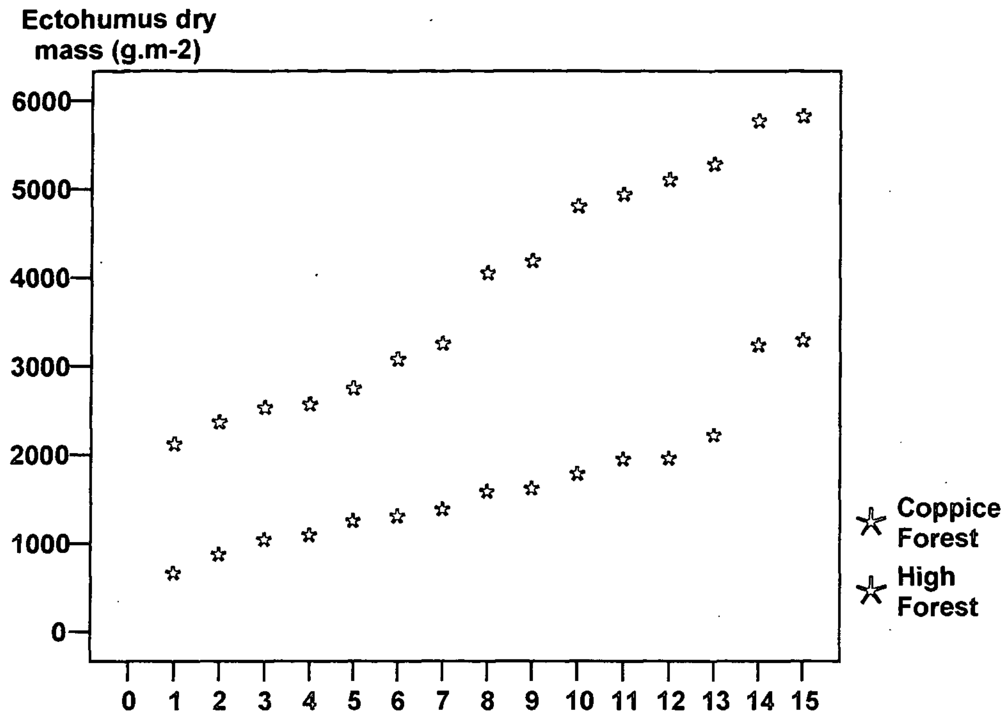


Figure 4.1 Ranges of humus dry mass in the high and coppice forest in the Vienna Woods (ranked in increasing order)

Table 4.2 One-sample T-test results for humus dry mass between the high and coppice forest (n=15)

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Coppice forest	8,44	14	0,000	1682	1255	2110
High forest	11,53	14	0,000	3905	3179	4632

4.2 Root dry mass

The roots were classified into fine roots as diameter smaller than 2 mm and coarse roots as the diameter not smaller than 2 mm. I collected the soil roots among the different soil depth (0 to 5, 5 to 10, 10 to 20, 20 to 40 and 40+ cm) and determined the dry mass (Table 4.3) as the same of humus after drying it up to constant weight at 105 ° C.

Table 4.3 Root dry mass ($g.m^{-3}$) at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth	Coppice forest patch				High forest patch			
(cm)	Profile No.	Profile Length(cm)	Coarse root (g.m-3)	Fine root (g.m-3)	Profile No.	Profile Length(cm)	Coarse root (g.m-3)	Fine root (g.m-3)
0-5			831,9	5459,4			0,0	4107,5
5-10			0,0	1871,8			26205,0	1819,8
10-20	N1	58	182,0	857,9	H1	53	11724,9	649,9
20-40			870,9	481,0			273,0	546,0
40+			158,9	491,1			5511,5	1091,9
0-5			0,0	7591,1			0,0	208,0
5-10			675,9	4783,4			3691,6	1143,9
10-20	N2	51	1429,9	3795,7	H2	53	0,0	1247,9
20-40			8111,3	1195,9			0,0	481,0
40+			0,0	519,9			0,0	1021,3
0-5			0,0	8787,0			467,9	2287,7
5-10			0,0	2755,7			1871,8	1559,8
10-20	N3	53	5979,5	805,9	H3	51	3275,7	1039,9
20-40			0,0	416,0			442,0	753,9
40+			0,0	380,0			0,0	614,5
0-5			467,9	11750,6			0,0	6343,3
5-10			3691,6	1819,8			0,0	3795,6
10-20	N4	51	649,9	987,9	H4	46	0,0	1741,8
20-40			0,0	520,0			130,0	831,9
40+			0,0	1323,5			0,0	378,1
0-5			0,0	5251,4			0,0	2911,7
5-10			0,0	1091,9			0,0	3379,6
10-20	N5	58	1143,9	1247,9	H5	50	935,9	2547,8
20-40			390,0	481,0			44027,0	1468,9
40+			881,0	491,1			4831,2	801,6
0-5			0,0	6083,3			0,0	727,9
5-10			416,0	2859,7			0,0	1195,9
10-20	N6	51	260,0	1325,9	H6	54	0,0	1897,8
20-40			3275,7	974,9			28337,4	1299,9
40+			0,0	709,0			0,0	1252,6
0-5			0,0	9306,9			0,0	6863,2
5-10			0,0	8163,1			467,9	5667,3
10-20	N7	54	6785,4	2365,8	H7	55	4705,6	2547,8
20-40			1676,8	844,9			4328,6	1676,8
40+			501,4	520,0			0,0	649,9
0-5			467,9	3587,6			0,0	2755,7
5-10			1923,8	2079,8			0,0	3535,6
10-20	N8	53	1767,8	1065,9	H8	51	0,0	2131,8
20-40			1299,9	623,9			727,9	1884,8
40+			761,4	315,7			278,5	854,2
0-5			0,0	3951,5			0,0	2339,7
5-10			1247,9	2079,8			2495,7	1559,8
10-20	N9	53	675,9	1091,9	H9	50	0,0	1039,9
20-40			6291,4	494,0			844,9	636,9
40+			3610,7	635,5			100,0	539,9
0-5			260,0	11230,7			2079,8	8891,0
5-10			7435,1	2547,7			1923,8	4211,5
10-20	N10	54	2001,8	2469,8	H10	54	10217,1	2365,8
20-40			6863,4	1117,9			0,0	688,9
40+			2024,1	501,4			500,0	919,9

Table 4.3 (continued)

Soil depth	Coppice forest patch				High forest patch			
(cm)	Profile No.	Profile Length(cm)	Coarse root (g.m-3)	Fine root (g.m-3)	Profile No.	Profile Length(cm)	Coarse root (g.m-3)	Fine root (g.m-3)
0-5			0,0	4107,5			0,0	2911,7
5-10			779,9	2079,8			1559,8	1195,9
10-20	N11	54	2287,8	779,9	H11	51	1039,9	1221,9
20-40			753,9	675,9			234,0	1065,9
40+			3444,7	823,3			0,0	872,8
0-5			416,0	8007,1			0,0	2443,7
5-10			0,0	2703,7			0,0	3639,6
10-20	N12	54	6499,4	1299,9	H12	51	1897,8	1429,9
20-40			1819,8	1000,9			260,0	675,9
40+			0,0	945,4			0,0	819,9
0-5			0,0	14818,3			0,0	4315,5
5-10			0,0	2235,7			0,0	2287,7
10-20	N13	49	8163,3	1637,9	H13	52	5615,5	1091,9
20-40			32965,0	1533,9			195,0	546,0
40+			546,0	987,9			639,9	519,9
0-5			4055,5	10346,8			0,0	2911,7
5-10			5563,4	1559,8			0,0	935,9
10-20	N14	54	1481,9	1247,9	H14	51	0,0	1273,9
20-40			8670,2	935,9			1026,9	623,9
40+			0,0	779,9			1213,2	1603,2
0-5			0,0	20381,6			1455,8	4055,5
5-10			1819,8	3587,6			2547,7	4835,4
10-20	N15	52	3301,7	1845,8	H15	54	0,0	3249,7
20-40			3769,7	1572,9			11166,0	1364,9
40+			5577,6	1229,0			3286,8	947,1

Figure 4.2 shows dry mass ($g.m^{-3}$) of fine roots is higher than the dry mass ($g.m^{-3}$) of coarse roots at the soil depth 0 to 5 cm both in the high and coppice forest in the Vienna woods. At the soil depth 0 to 5 cm the dry mass ($g.m^{-3}$) of fine roots and coarse roots in the coppice forest are higher than in the high forest. With the increase of the soil depth, the coarse roots dry mass is increasing and higher than the fine roots dry mass both in the high and coppice forest. The dry mass of coarse roots has a maximum value both in the high and coppice forest at the soil depth 20 to 40 cm and the high forest is a little bit higher than the coppice forest.

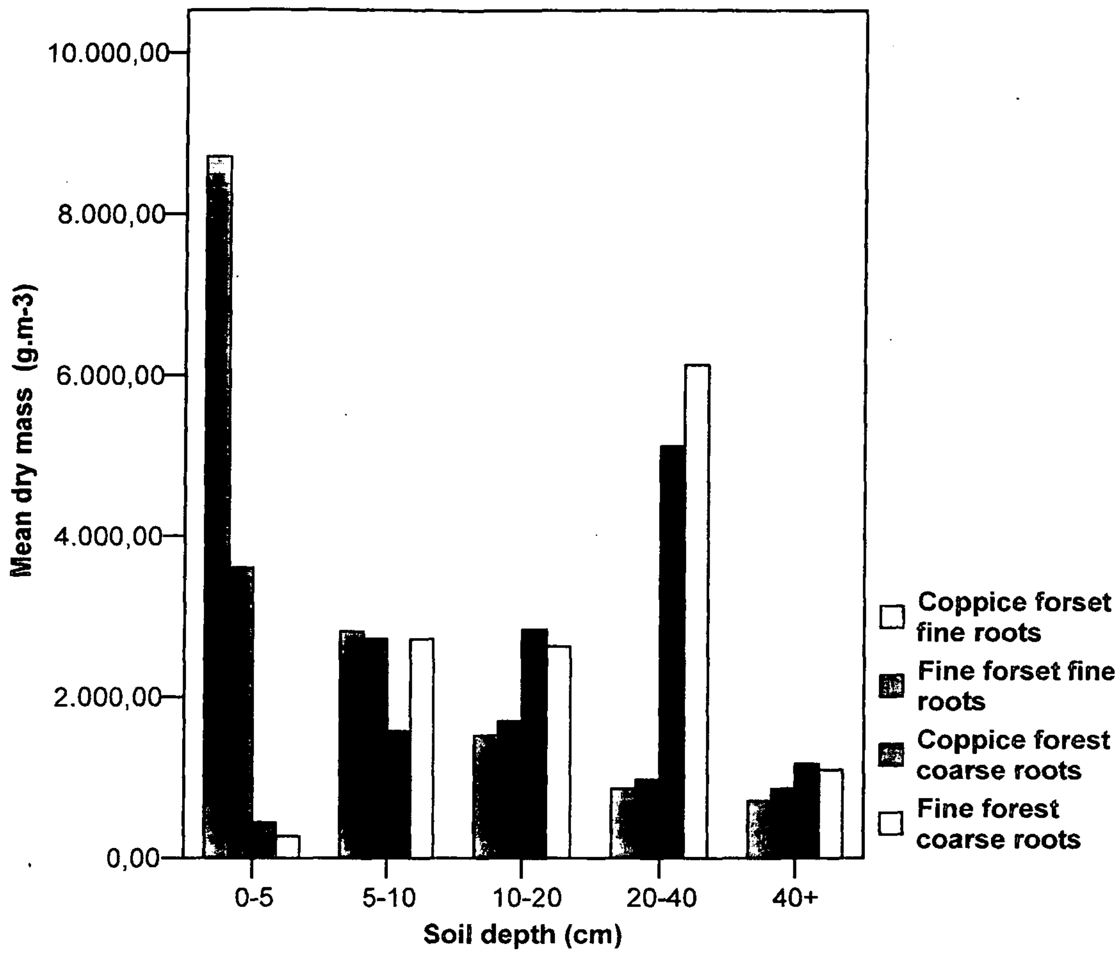


Figure 4.2 Mean dry mass (g.m^{-3}) of fine roots and coarse roots at different soil depths in the high and coppice forest in the Vienna Woods (n=15)

Mean value of fine roots dry mass and total roots dry mass is significantly higher at the upper soil depth 0 to 5 cm in the coppice forest in the Vienna Woods. There is no significant difference of soil roots dry mass between high and coppice forest in the other soil depth according to the one-way analysis of variance (Table 4.4).

Table 4.4 Mean value, ANOVA results for dry mass (g.m^{-3}) of fine roots, coarse roots and total roots at different soil depths in the high and coppice forest in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05, the same letter are not significantly different at the 0.05 level of significance) (n=15)**

Roots dry mass	Forest patches	Soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+
Fine roots	Coppice forest	8710,7^{b}	2814,6^{a}	1521,7^{a}	857,9^{a}	710,2^{a}
	High forest	3604,9^{a}	2717,6^{a}	1698,5^{a}	969,7^{a}	869,1^{a}
p		0.01**	0,871	0,538	0,471	0,194
Coarse roots	Coppice forest	433,3^{a}	1570,2^{a}	2840,7^{a}	5117,2^{a}	1167,0^{a}
	High forest	266,9^{a}	2717,6^{a}	2627,5^{a}	6132,8^{a}	1090,7^{a}
p		0,599	0,53	0,861	0,799	0,908
Total roots	Coppice forest	9144,0^{b}	4384,8^{a}	4362,4^{a}	5975,1^{a}	1877,2^{a}
	High forest	3871,8^{a}	5435,1^{a}	4326,0^{a}	7102,6^{a}	1949,9^{a}
p		0.001***	0,564	0,977	0,782	0,917

4.3 Soil bulk density

Soil bulk density (g.cm^{-3}) (Table 4.5) from the two forest patches is separately compared among the different 5 soil depths (0 to 5, 5 to 10, 10 to 20, 20 to 40 and 40 + cm).

From the graph (Figure 4.3) we can see that the soil bulk density is increasing with the increased soil depth both in the high and coppice forest. Observably the soil bulk density in the high forest is higher than in the coppice forest at the upper soil depth 40 cm. The mean value of the soil bulk density at the upper soil depth 0 to 5 cm is 0.787 g.cm^{-3} in the coppice forest and 0.881 g.cm^{-3} in the high forest in the Vienna woods. The mean value is more than 1.3 g.cm^{-3} after the depth of 40 cm and there is no obvious difference between high and coppice forest in the research area.

Table 4.5 Soil bulk density (g.cm^{-3}) at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth (cm)	Coppice forest patch			High forest patch		
	Profile No.	Profile Length(cm)	Soil bulk density (g.cm-3)	Profile No.	Profile Length(cm)	Soil bulk density (g.cm-3)
0-5			0,93			0,98
5-10			1,03			1,17
10-20	N1	58	1,03	H1	53	1,00
20-40			1,33			1,42
40+			1,35			1,89
0-5			0,74			0,87
5-10			0,96			1,01
10-20	N2	51	1,23	H2	53	1,11
20-40			1,29			1,28
40+			1,21			1,25
0-5			0,83			0,93
5-10			1,11			1,14
10-20	N3	53	1,00	H3	51	1,13
20-40			1,32			1,10
40+			1,13			1,40
0-5			0,68			0,83
5-10			0,95			1,05
10-20	N4	51	1,12	H4	46	1,12
20-40			0,99			1,27
40+			1,41			0,91
0-5			0,56			1,02
5-10			1,04			1,10
10-20	N5	58	1,01	H5	50	1,22
20-40			1,09			1,23
40+			1,46			1,15
0-5			0,72			0,38
5-10			1,01			1,01
10-20	N6	51	0,97	H6	54	1,16
20-40			1,25			1,12
40+			1,36			1,84
0-5			0,86			0,49
5-10			1,15			1,13
10-20	N7	54	1,29	H7	55	1,26
20-40			1,27			1,34
40+			1,30			1,60
0-5			0,83			0,77
5-10			0,90			1,26
10-20	N8	53	1,49	H8	51	1,16
20-40			1,30			1,22
40+			1,31			1,29
0-5			1,22			0,86
5-10			1,25			1,06
10-20	N9	53	1,29	H9	50	1,18
20-40			1,09			1,41
40+			1,60			1,22
0-5			0,71			1,00
5-10			0,86			1,49
10-20	N10	54	0,98	H10	54	1,24
20-40			1,16			1,34
40+			1,26			1,46

Table 4.5 (continued)

Soil depth (cm)	Coppice forest patch			High forest patch		
	Profile No.	Profile Length(cm)	Soil bulk density (g.cm-3)	Profile No.	Profile Length(cm)	Soil bulk density (g.cm-3)
0-5			0,64			1,00
5-10			0,79			1,28
10-20	N11	54	1,17	H11	51	1,26
20-40			1,21			1,35
40+			1,41			1,18
0-5			0,90			1,17
5-10			0,88			1,25
10-20	N12	54	1,22	H12	51	1,09
20-40			1,16			1,26
40+			1,39			1,05
0-5			0,50			0,84
5-10			1,09			1,33
10-20	N13	49	1,12	H13	52	1,23
20-40			1,15			1,42
40+			1,07			1,26
0-5			0,93			1,21
5-10			0,98			1,31
10-20	N14	54	1,24	H14	51	1,71
20-40			1,38			1,55
40+			1,10			1,42
0-5			0,76			0,87
5-10			1,11			1,15
10-20	N15	52	0,95	H15	54	0,86
20-40			1,28			1,27
40+			1,96			1,18

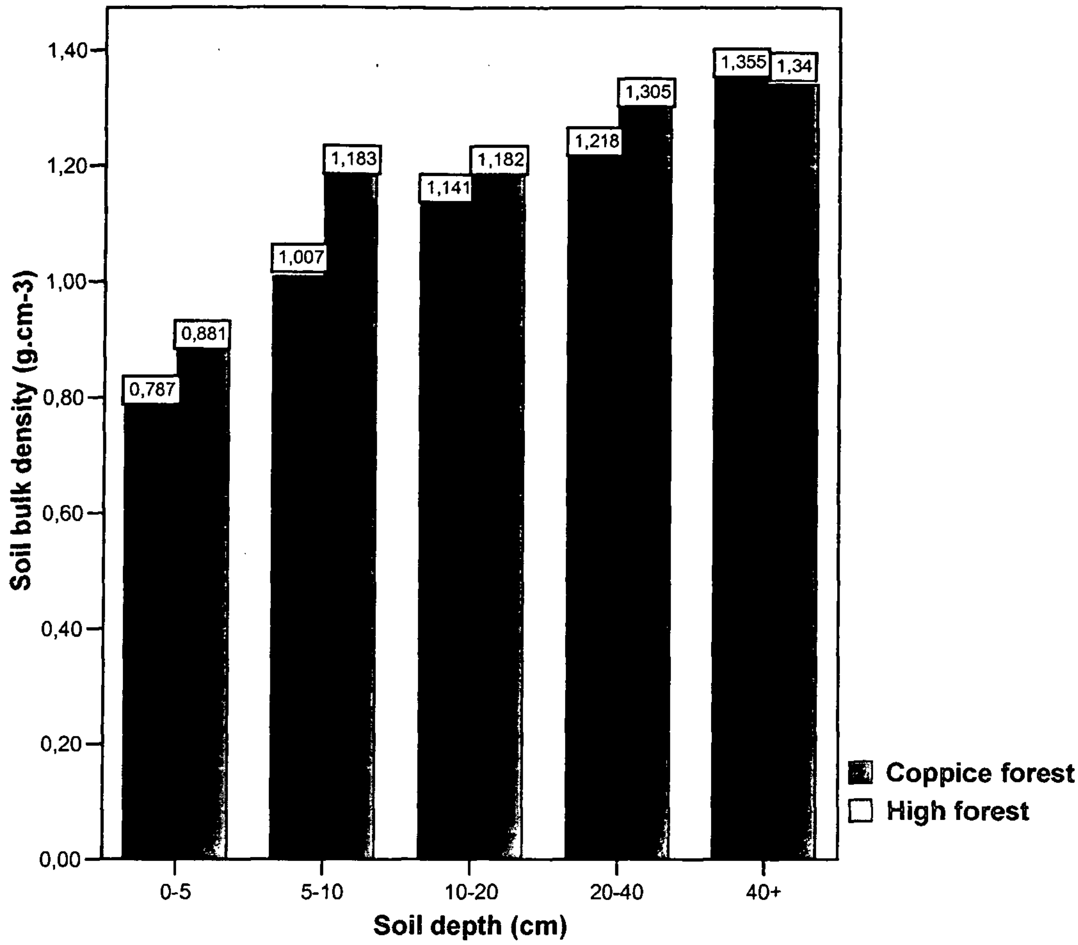


Figure 4.3 Mean value of soil bulk density (g.cm^{-3}) at different soil depths in the high and coppice forest in the Vienna Woods (n=15)

For comparing the soil bulk density (g.cm^{-3}) among the different soil depth in the high and coppice forest, a one-way analysis of variance was used (Table 4.6).

Table 4.6 ANOVA results for the soil bulk density (g.cm^{-3}) at different soil depths in the high and coppice forest in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05) (n=15)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,000***	0,000***	0,000***	0,000***	0,197	0,000***	0,000***	0,000***	0,000***
	5 to 10	0,000***		0,024*	0,000***	0,000***	0,110	0,008**	0,012*	0,000***	0,000***
	10 to 20	0,000***	0,024*		0,118	0,014*	0,002**	0,433	0,430	0,002**	0,040*
	20 to 40	0,000***	0,000***	0,118		0,068	0,000***	0,418	0,487	0,046*	0,054
	40+	0,000***	0,000***	0,014*	0,068		0,000***	0,038*	0,082	0,482	0,886
High forest soil depth (cm)	0 to 5	0,197	0,110	0,002**	0,000***	0,000***		0,000***	0,000***	0,000***	0,001***
	5 to 10	0,000***	0,008**	0,433	0,418	0,038*	0,000***		0,989	0,004**	0,065
	10 to 20	0,000***	0,012*	0,430	0,487	0,082	0,000***	0,989		0,009**	0,073
	20 to 40	0,000***	0,000***	0,002**	0,046*	0,482	0,000***	0,004**	0,009**		0,653
	40+	0,000***	0,000***	0,040*	0,054	0,886	0,001***	0,065	0,073	0,653	

There is no significant difference in the soil bulk density at the soil depth 0 to 5, 10 to 20 and 40+cm, a high significant difference at the soil depth 5 to 10 cm and significant difference at the soil depth 20 to 40cm between the high and coppice forest in the Vienna Woods (Table 4.7).

Table 4.7 Mean value ± standard errors, ANOVA results for the soil bulk density ($g.cm^{-3}$) in the high and coppice forest at different soil depths in the Vienna Woods (*$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$, the same letter are not significantly different at the 0.05 level of significance) (n=15)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	$0,78 \pm 0,05^a$	$1,01 \pm 0,03^a$	$1,14 \pm 0,04^b$	$1,22 \pm 0,03^b$	$1,36 \pm 0,06^c$
High forest	$0,88 \pm 0,06^a$	$1,18 \pm 0,04^b$	$1,18 \pm 0,05^b$	$1,31 \pm 0,04^c$	$1,34 \pm 0,08^c$
P	0.205	0,001**	0,506	0,044*	0,872

4.4 Soil acidity

Soil acidity was determined by the active acidity (soil pH H_2O) and the exchanged acidity (soil pH $CaCl_2$) in this study (Table 4.8).

Figure 4.4 shows that the soil pH in the coppice forest is higher than in the high forest at all soil depth. The H_2O pH value and the $CaCl_2$ pH is decreasing from the upper soil depth to the soil depth 5 to 10 cm and increasing from 5 to 10 cm to deeper depth in the coppice forest in the research area. Similarly the high forest has the same tendency, but the minimum pH value is at the soil depth10 to 20 cm.

Table 4.8 Soil pH at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth	Coppice forest patch			High forest patch		
(cm)	Profile No.	pH H2O	pH CaCl2	Profile No.	pH H2O	pH CaCl2
0-5		5,1	4,2		4,9	3,8
5-10		4,9	3,8		4,9	3,7
10-20	N1	4,9	3,7	H1	5,0	3,8
20-40		5,0	3,8		5,0	3,9
40+		5,1	4,0		5,3	4,1
0-5		5,5	4,3		4,8	3,8
5-10		5,0	3,9		4,8	3,8
10-20	N2	5,4	4,2	H2	4,8	3,9
20-40		5,5	4,3		5,0	4,0
40+		5,6	4,2		5,1	4,0
0-5		5,7	5,0		5,0	3,9
5-10		5,6	4,8		4,8	3,7
10-20	N3	5,3	4,2	H3	4,8	3,6
20-40		5,0	3,9		4,7	3,6
40+		4,9	3,7		4,7	3,7
0-5		4,7	3,8		5,1	4,1
5-10		4,6	3,6		5,0	4,0
10-20	N4	4,7	3,7	H4	5,0	3,9
20-40		4,9	3,9		5,1	4,0
40+		5,3	4,1		5,2	4,2
0-5		4,8	3,8		5,1	4,1
5-10		4,7	3,7		4,8	3,7
10-20	N5	4,5	3;5	H5	4,6	3,6
20-40		4,8	3,7		4,7	3,7
40+		5,2	4,1		5,0	4,0
0-5		4,6	3,6		5,4	4,6
5-10		4,5	3,5		5,4	4,4
10-20	N6	4,6	3,6	H6	5,3	4,2
20-40		4,7	3,6		4,9	4,0
40+		4,9	3,9		5,1	4,0
0-5		5,1	3,8		5,3	4,3
5-10		5,0	3,8		5,0	3,9
10-20	N7	5,0	3,9	H7	4,7	3,6
20-40		5,3	4,0		4,7	3,6
40+		5,4	4,1		4,6	3,6
0-5		4,9	3,8		4,7	3,7
5-10		4,8	3,7		4,5	3,5
10-20	N8	4,9	3,8	H8	4,6	3,6
20-40		5,3	4,1		4,8	3,8
40+		5,4	4,3		4,9	3,8
0-5		5,1	3,9		5,0	3,8
5-10		5,2	3,9		4,7	3,7
10-20	N9	5,3	4,0	H9	4,5	3,6
20-40		5,4	4,1		4,5	3,7
40+		5,2	4,0		4,6	3,7
0-5		4,9	3,9		4,8	3,8
5-10		4,7	3,5		4,8	3,7
10-20	N10	4,7	3,6	H10	4,7	3,7
20-40		4,6	3,6		4,7	3,7
40+		5,0	4,1		4,8	3,8

Table 4.8(continued)

Soil depth (cm)	Coppice forest patch Profile No.	pH H2O	pH CaCl2	High forest patch Profile No.	pH H2O	pH CaCl2
0-5		5,1	4,0		4,8	3,9
5-10		4,9	3,7		4,7	3,7
10-20	N11	4,9	3,6	H11	4,6	3,6
20-40		4,8	3,6		4,7	3,7
40+		5,0	3,8		4,9	3,9
0-5		5,3	4,1		4,8	3,8
5-10		5,2	4,0		4,5	3,5
10-20	N12	5,2	4,0	H12	4,5	3,6
20-40		5,3	4,0		4,6	3,7
40+		5,6	4,2		4,6	3,7
0-5		4,8	3,8		5,0	4,0
5-10		4,5	3,5		4,7	3,6
10-20	N13	4,6	3,6	H13	4,7	3,7
20-40		4,6	3,7		4,8	3,7
40+		4,7	3,8		5,2	4,1
0-5		5,3	4,2		5,1	3,9
5-10		5,4	4,2		4,9	3,7
10-20	N14	5,3	4,1	H14	4,8	3,7
20-40		5,5	4,4		4,8	3,7
40+		5,7	4,6		5,2	4,1
0-5		5,0	3,9		5,1	4,0
5-10		4,6	3,5		4,9	3,7
10-20	N15	4,7	3,5	H15	4,8	3,7
20-40		4,8	3,7		4,7	3,6
40+		5,1	4,0		5,2	4,1

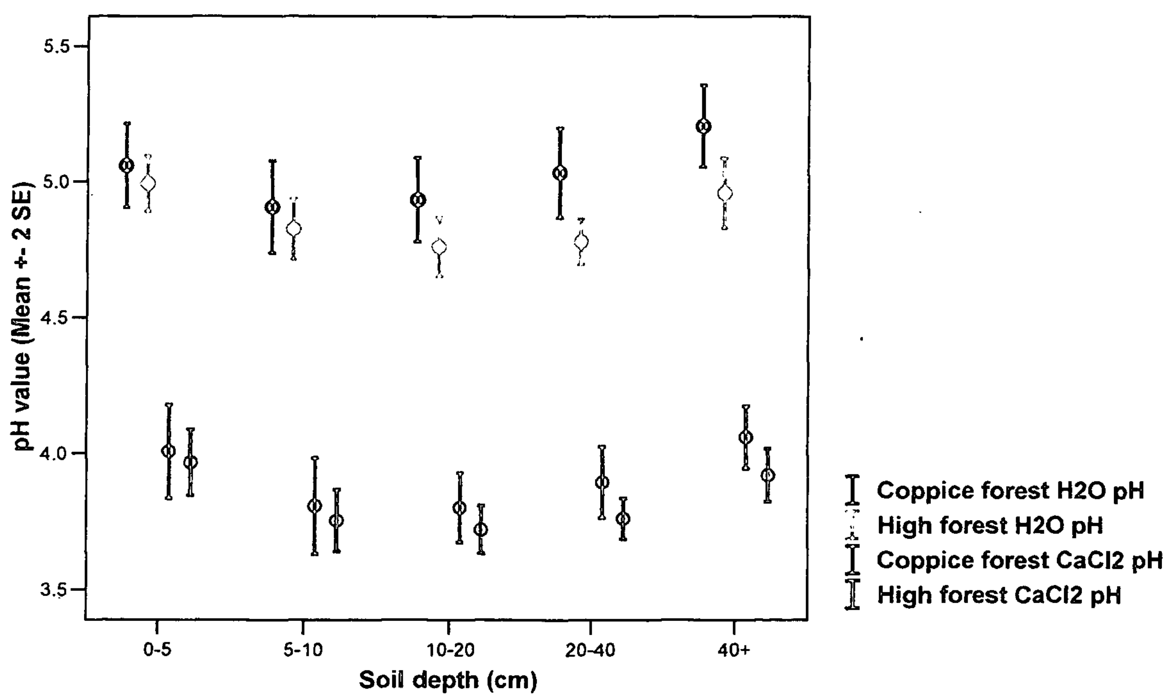


Figure 4.4 Soil pH value (mean ±2SE) at different soil depths in the high and coppice forest in the Vienna Woods (n=15)

4.4.1 Active acidity

There is no significant difference in the soil H_2O pH value at the soil depth 0 to 5, 5 to 10 and 10 to 20 cm for the two forest patches. The soil H_2O pH value in the coppice forest was significantly higher than in the high forest at the soil depth 20 to 40 and 40+ cm (Table 4.9).

Table 4.9 Mean value ± standard errors, ANOVA results for the soil H_2O pH in the high and coppice forest at different soil depths in the Vienna Woods (*p≤ 0.001, **p≤0.01, *p≤0.05, the same letter are not significantly different at the 0.05 level of significance) (n=15)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	5,06±0.08^{a}	4,91±0,09^{a}	4,93±0,08^{a}	5,03±0,08^{b}	5,21±0,08^{b}
High forest	4,99±0,05^{a}	4,83±0,06^{a}	4,76±0,06^{a}	4,78±0,04^{a}	4,96±0,06^{a}
P	0,478	0,441	0,08	0,011*	0,019*

Soil H_2O pH from high and coppice forest were compared at different soil depths by using one-way analysis of variance (Table 4.10)

Table 4.10 ANOVA results for the soil H_2O pH value at different soil depths in the high and coppice forest in the Vienna Woods (*$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$) (n=15)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,002**	0,005**	0,722	0,113	0,541	0,054	0,014*	0,011*	0,687
	5 to 10	0,002**			0,086	0,004**	0,433	0,502	0,226	0,259	0,687
	10 to 20	0,005**	0,524		0,046*	0,002**	0,577	0,348	0,129	0,129	0,826
	20 to 40	0,722	0,086	0,046*		0,002**	0,709	0,089	0,029*	0,019*	0,549
	40+	0,113	0,004**	0,002**	0,002**		0,047*	0,003**	0,001***	0,000***	0,034*
High forest soil depth (cm)	0 to 5	0,541	0,433	0,577	0,709	0,047*		0,000***	0,000***	0,005**	0,670
	5 to 10	0,054	0,502	0,348	0,089	0,003**	0,000***		0,036*	0,396	0,070
	10 to 20	0,014*	0,226	0,129	0,029*	0,001**	0,000***	0,036*		0,607	0,002**
	20 to 40	0,011*	0,259	0,129	0,019*	0,000***	0,005**	0,396	0,607		0,001***
	40+	0,687	0,687	0,826	0,549	0,034*	0,670	0,070	0,002**	0,001***	

4.4.2 Exchangeable acidity

Exchangeable acidity was determined in 0.01 M $CaCl_2$ soil suspensions. Table 4.11 shows the difference of soil $CaCl_2$ pH value among the different soil depths for the two forest patches.

Table 4.11 ANOVA results for the soil $CaCl_2$ pH value at different soil depths in the high and coppice forest in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05) (n=15)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,000***	0,006**	0,231	0,638	0,754	0,048*	0,017*	0,029*	0,435
	5 to 10	0,000***		0,902	0,296	0,030*	0,207	0,653	0,449	0,666	0,348
	10 to 20	0,006**	0,902		0,029*	0,003**	0,125	0,622	0,351	0,601	0,228
	20 to 40	0,231	0,296	0,029*		0,004**	0,496	0,169	0,059	0,088	0,764
	40+	0,638	0,030*	0,003**	0,004**		0,334	0,004*	0,000***	0,000***	0,071
High forest soil depth (cm)	0 to 5	0,754	0,207	0,125	0,496	0,334		0,000***	0,000***	0,007**	0,529
	5 to 10	0,048*	0,653	0,622	0,169	0,004**	0,000***		0,313	0,892	0,024*
	10 to 20	0,017*	0,449	0,351	0,059	0,000***	0,000***	0,313		0,138	0,001***
	20 to 40	0,029*	0,666	0,601	0,088	0,000***	0,007**	0,892	0,138		0,003**
	40+	0,435	0,348	0,228	0,764	0,071	0,529	0,024*	0,001***	0,003**	

There is no significant difference in the soil $CaCl_2$ pH value at different soil depths between the high and coppice forest in the Vienna Woods (Table 4.12).

Table 4.12 Mean value ± standard errors, ANOVA results for the soil $CaCl_2$ pH in the high and coppice forest at different soil depths in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05, the same letter are not significantly different at the 0.05 level of significance) (n=15)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	4,01±0,09[a]	3,81±0,09[a]	3,80±0,06[a]	3,89±0,07[a]	4,06±0,06[a]
High forest	3,97±0,06[a]	3,75±0,06[a]	3,72±0,04[a]	3,76±0,04[a]	3,92±0,05[a]
P	0,708	0,616	0,311	0,089	0,075

4.5 Nitrogen

Soil nitrogen content ($g.m^{-2}.cm^{-1}$) from the high and coppice forest (Table 4.13) were separately compared at the different soil depths in the Vienna Woods.

Generally, the coppice forest has higher nitrogen content than the high forest at the soil depths 0 to 5, 10 to 20, 20 to 40 and 40+ cm in the research area. The nitrogen content is higher at the soil depth 5 to 10 cm in this study. The nitrogen content is decreasing with the increase of the soil depth both in the high and coppice forest in the research area (Figure 4.5).

Table 4.13 Soil nitrogen content (g.m^{-2}.cm^{-1}) at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth (cm)	Coppice forest patch Profile No.	Nitrogen Content (g.m-2.cm-1)	High forest patch Profile No.	Nitrogen Content (g.m-2.cm-1)
0-5	N1	24,80	H1	23,86
5-10		13,93		14,82
10-20		10,00		9,37
20-40		7,54		8,46
40+		4,60		10,66
0-5	N2	21,03	H2	18,57
5-10		15,58		14,19
10-20		14,90		11,84
20-40		7,99		7,56
40+		5,26		6,84
0-5	N3	23,45	H3	17,12
5-10		13,40		19,35
10-20		7,26		13,23
20-40		5,72		6,67
40+		4,97		5,81
0-5	N4	21,63	H4	22,50
5-10		11,65		18,24
10-20		10,58		14,03
20-40		6,61		8,86
40+		7,56		4,50
0-5	N5	14,76	H5	26,61
5-10		14,74		16,82
10-20		12,36		16,18
20-40		7,79		11,14
40+		8,21		3,47
0-5	N6	21,79	H6	11,31
5-10		15,48		14,28
10-20		10,67		8,20
20-40		10,15		5,00
40+		8,61		6,04
0-5	N7	19,75	H7	19,51
5-10		13,12		21,59
10-20		11,33		10,36
20-40		6,62		7,12
40+		5,56		5,38
0-5	N8	24,58	H8	17,38
5-10		9,68		16,87
10-20		13,60		10,22
20-40		7,63		7,56
40+		6,01		6,79
0-5	N9	21,59	H9	14,53
5-10		13,69		12,32
10-20		13,22		8,78
20-40		10,03		6,25
40+		8,11		3,40
0-5	N10	22,41	H10	11,08
5-10		10,95		14,07
10-20		10,99		7,25
20-40		8,67		5,75
40+		7,68		5,18

Table 4.13 (continued)

Soil depth (cm)	Coppice forest patch		High forest patch	
	Profile No.	Nitrogen Content (g.m-2.cm-1)	Profile No.	Nitrogen Content (g.m-2.cm-1)
0-5		21,10		19,61
5-10		14,20		17,42
10-20	N11	11,81	H11	9,74
20-40		7,97		6,37
40+		8,08		4,13
0-5		22,72		17,90
5-10		12,31		12,50
10-20	N12	11,30	H12	6,83
20-40		7,38		5,80
40+		6,31		3,60
0-5		24,73		20,59
5-10		20,55		12,91
10-20	N13	14,50	H13	8,67
20-40		10,13		7,31
40+		7,04		5,68
0-5		26,01		21,38
5-10		10,79		11,51
10-20	N14	8,41	H14	11,90
20-40		6,87		6,62
40+		4,98		5,96
0-5		26,17		13,26
5-10		17,39		7,68
10-20	N15	12,10	H15	4,23
20-40		6,95		4,71
40+		8,92		4,47

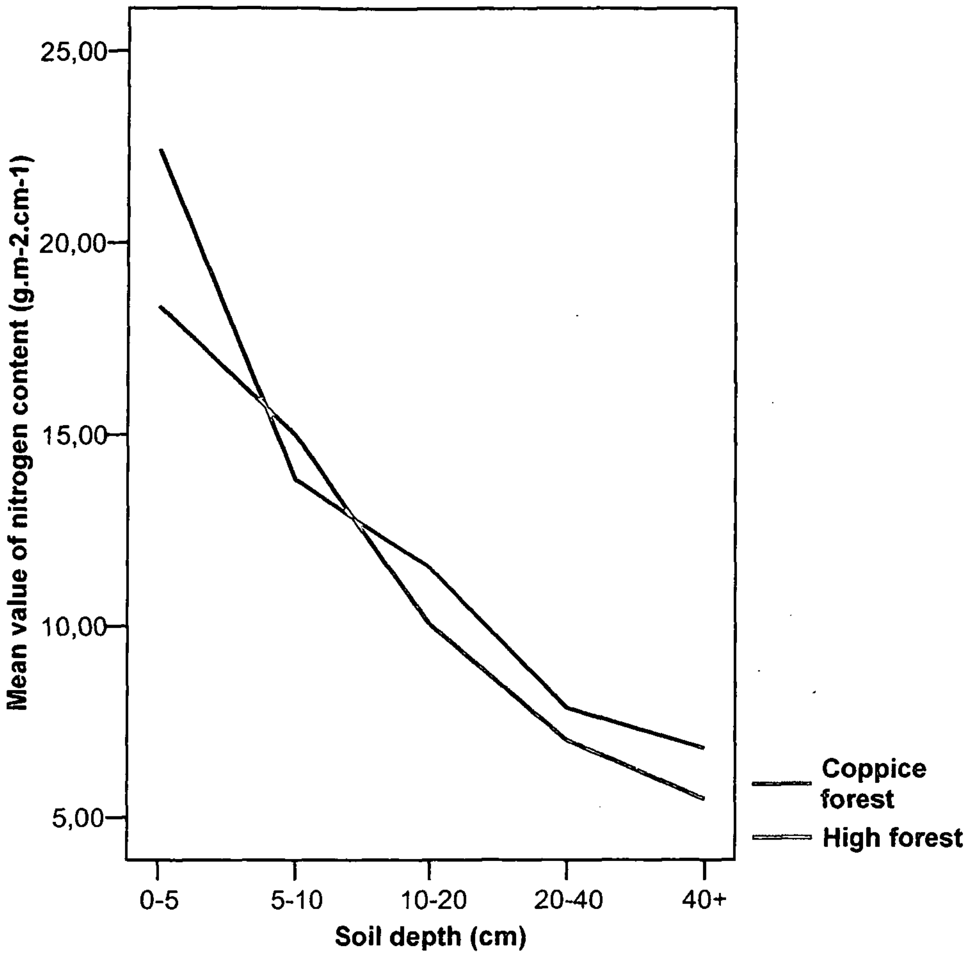


Figure 4.5 Mean value of soil nitrogen content ($g.m^{-2}.cm^{-1}$) at different soil depths in the high and coppice forest in the Vienna Woods (n=15)

Table 4.14 shows the difference of nitrogen content ($g.m^{-2}.cm^{-1}$) among the different soil depths for the two forest patches in the research area.

Table 4.14 ANOVA results for the soil nitrogen content ($g.m^{-2}.cm^{-1}$) at different soil depths in the high and coppice forest in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05) (n=15)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,000***	0,000***	0,000***	0,000***	0,020*	0,000***	0,000***	0,000***	0,000***
	5 to 10	0,000***		0,005**	0,000***	0,000***	0,005**	0,402	0,006**	0,000***	0,000***
	10 to 20	0,000***	0,005**		0,000***	0,000***	0,000***	0,010**	0,173	0,000***	0,000***
	20 to 40	0,000***	0,000***	0,000***		0,012*	0,000***	0,000***	0,040*	0,173	0,001***
	40+	0,000***	0,000***	0,000***	0,012*		0,000***	0,000***	0,040*	0,731	0,108
High forest soil depth (cm)	0 to 5	0,020*	0,005**	0,000***	0,000***	0,000***		0,013*	0,000***	0,000***	0,000***
	5 to 10	0,000***	0,402	0,010**	0,000***	0,000***	0,013*		0,000***	0,000***	0,000***
	10 to 20	0,000***	0,006**	0,173	0,040*	0,040*	0,000***	0,000***		0,000***	0,000***
	20 to 40	0,000***	0,000***	0,000***	0,173	0,731	0,000***	0,000***	0,000***		0,020*
	40+	0,000***	0,000***	0,000***	0,001***	0,108	0,000***	0,000***	0,000***	0,020*	

There is no significant difference in the soil nitrogen content at the soil depth 5 to 10, 10 to 20 and 20 to 40 cm for the two forest patches. The soil nitrogen content ($g.m^{-2}.cm^{-1}$) in the coppice forest was significantly higher than in the high forest at the soil depth 0 to 5 and 40+ cm (Table 4.15).

Table 4.15 Mean value ± standard errors, ANOVA results for the soil nitrogen ($g.m^{-2}.cm^{-1}$) in the high and coppice forest at different soil depths in the Vienna Woods (*$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$, the same letter are not significantly different at the 0.05 level of significance) (n=15)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	22,43±0,74[a]	13,83±0,71[a]	11,54±0,54[a]	7,87±0,35[a]	6,79±0,38[a]
High forest	18,35±1,15[b]	14,97±0,90[a]	11,06±0,79[a]	7,01±0,42[a]	5,46±0,47[b]
P	0,006**	0,330	0,132	0,127	0,037*

4.6 Carbon

In this study we did not separate the soil organic carbon and inorganic carbon. The total soil carbon content ($g.m^{-2}.cm^{-1}$) from two research areas (Table 4.16) was separately compared at different soil depths.

Figure 4.6 shows that the soil carbon content ($g.m^{-2}.cm^{-1}$) in the coppice forest is obviously higher than in the high forest at the soil depth 0 to 5 cm in the research area. The value of carbon content becomes equal at the soil depth 5 to 10 cm. The carbon content in the coppice forest is higher than in the high forest again after the soil depth 5 to 10. With the increasing of the soil depth, the total soil carbon content is decreasing in both forest patches.

Table 4.16 Soil carbon content ($g.m^{-2}.cm^{-1}$) at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth (cm)	Coppice forest patch Profile No.	Coppice forest patch Carbon content (g.m-2.cm-1)	High forest patch Profile No.	High forest patch Carbon content (g.m-2.cm-1)
0-5		369,49		270,12
5-10		199,51		307,80
10-20	N1	135,75	H3	251,54
20-40		102,41		129,47
40+		48,02		86,52
0-5		307,77		389,23
5-10		232,85		230,23
10-20	N2	212,24	H5	223,38
20-40		88,43		151,66
40+		60,38		50,72
0-5		357,81		326,88
5-10		214,01		365,37
10-20	N3	135,00	H7	160,02
20-40		95,78		102,98
40+		44,21		51,57
0-5		386,58		284,90
5-10		182,64		258,93
10-20	N4	134,90	H8	157,53
20-40		87,42		109,11
40+		70,08		80,50
0-5		192,02		227,64
5-10		225,47		201,08
10-20	N5	195,94	H9	138,65
20-40		113,69		74,96
40+		61,73		33,26
0-5		405,79		337,00
5-10		244,22		233,48
10-20	N6	177,22	H10	133,55
20-40		130,75		81,26
40+		78,39		58,25
0-5		432,60		278,75
5-10		195,99		270,46
10-20	N10	186,00	H11	172,12
20-40		131,66		84,58
40+		79,87		43,91
0-5		335,17		282,61
5-10		250,83		204,25
10-20	N11	221,60	H12	123,50
20-40		127,17		83,34
40+		87,58		47,88
0-5		517,75		354,02
5-10		349,24		204,42
10-20	N13	239,79	H13	121,77
20-40		156,40		89,03
40+		77,38		47,12
0-5		462,58		381,76
5-10		203,60		215,63
10-20	N14	132,43	H14	196,99
20-40		78,44		66,80
40+		45,33		45,77
0-5		433,81		222,81
5-10		275,06		127,77
10-20	N15	213,18	H15	76,45
20-40		116,95		62,00
40+		94,30		38,97

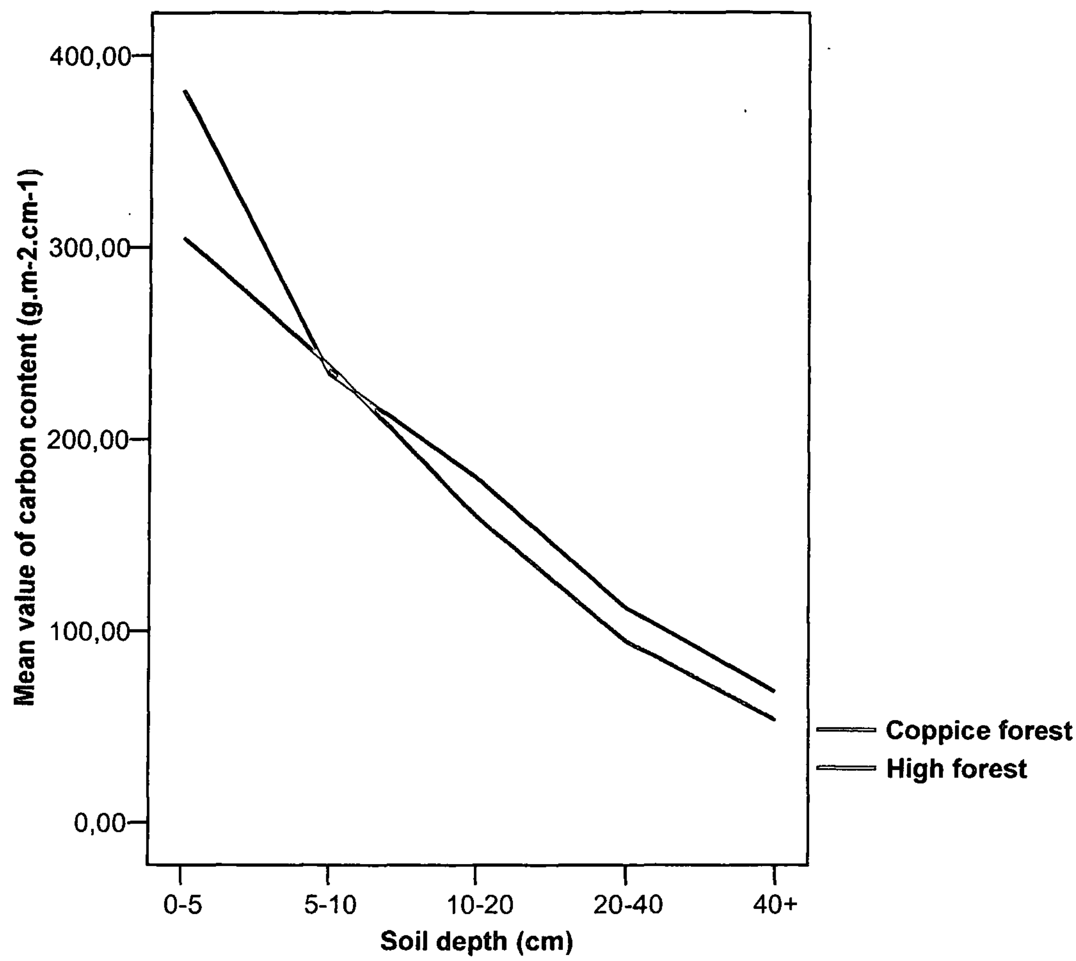


Figure 4.6 Mean value of soil carbon content ($g.m^{-2}.cm^{-1}$) at different soil depths in the high and coppice forest in the Vienna Woods (n=11)

Table 4.17 shows the difference of carbon content ($g.m^{-2}.cm^{-1}$) among the different soil depths for the two forest patches (Table 4.17).

Table 4.17 ANOVA results for the total soil carbon content ($g.m^{-2}.cm^{-1}$) at different soil depths in the high and coppice forest in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05) (n=11)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,000***	0,000***	0,000***	0,000***	0,014*	0,002**	0,000***	0,000***	0,000***
	5 to 10	0,000***		0,000***	0,000***	0,000***	0,007**	0,887	0,016*	0,000***	0,000***
	10 to 20	0,000***	0,000***		0,000***	0,000***	0,000***	0,068	0,401	0,000***	0,000***
	20 to 40	0,000***	0,000***	0,000***		0,000***	0,000***	0,000***	0,037*	0,194	0,000***
	40+	0,000***	0,000***	0,000***	0,000***		0,000***	0,000***	0,001***	0,044*	0,101
High forest soil depth (cm)	0 to 5	0,014*	0,007**	0,000***	0,000***	0,000***		0,014*	0,000***	0,000***	0,000***
	5 to 10	0,002**	0,887	0,068	0,000***	0,000***	0,014*		0,001***	0,000***	0,000***
	10 to 20	0,000***	0,016*	0,401	0,037*	0,001***	0,000***	0,001***		0,000***	0,000***
	20 to 40	0,000***	0,000***	0,000***	0,194	0,044*	0,000***	0,000***	0,000***		0,000***
	40+	0,000***	0,000***	0,000***	0,000***	0,101	0,000***	0,000***	0,000***	0,000***	

There is a significant difference in the total soil carbon content ($g.m^{-2}.cm^{-1}$) at the soil depth 0 to 5 cm for the two forest patches (Table 4.18).

Table 4.18 Mean value ± standard errors, ANOVA results for the total soil carbon content ($g.m^{-2}.cm^{-1}$) in the high and coppice forest at different soil depths in the Vienna Woods (*p≤0.001, **p≤0.01, *p≤0.05, the same letter are not significantly different at the 0.05 level of significance) (n=11)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	381,94±86,77[a]	233,95±46,93[a]	180,37±40,03[a]	111,74±23,68[a]	67,93±17,30[a]
High forest	305,06±56,97[b]	238,14±62,41[a]	159,60±49,83[a]	94,12±27,23[a]	53,15±16,41[a]
P	0,023*	0,861	0,294	0,121	0,053

4.7 C/N ration

Comparison of the C/N ration (Table 4.19) was made between two forest patches and among different soil depths in this study.

The C/N ration at the upper soil 20 cm depth is between 16 and 17.5. It decreased to around 14 at soil depth 20 to 40 cm. The C/N ratio in the high forest is higher than in the coppice forest in the research area (Figure 4.7)

Table 4.19 Soil C/N ration at different soil depths in the high and coppice forest in the Vienna Woods

Soil depth	Coppice forest patch		High forest patch	
(cm)	Profile No.	C/N ration	Profile No.	C/N ration
0-5		14,90		15,78
5-10		14,33		15,9
10-20	N1	13,57	H3	19,01
20-40		13,58		19,42
40+		10,44		14,89
0-5		14,63		14,63
5-10		14,95		13,69
10-20	N2	14,24	H5	13,81
20-40		11,08		13,61
40+		11,47		14,6
0-5		15,25		16,75
5-10		15,96		16,92
10-20	N3	18,60	H7	15,45
20-40		16,77		14,48
40+		8,89		9,58
0-5		17,87		16,39
5-10		15,67		15,35
10-20	N4	12,75	H8	15,41
20-40		13,22		14,42
40+		9,27		11,86
0-5		13,01		15,66
5-10		15,30		16,31
10-20	N5	15,85	H9	15,79
20-40		14,59		12,01
40+		7,53		9,78
0-5		18,62		30,42
5-10		15,77		16,6
10-20	N6	16,59	H10	18,41
20-40		12,88		14,13
40+		9,10		11,24
0-5		19,30		14,22
5-10		17,90		15,53
10-20	N10	16,92	H11	17,67
20-40		15,19		13,28
40+		10,39		10,63
0-5		15,88		15,79
5-10		17,66		16,34
10-20	N11	18,75	H12	18,07
20-40		15,95		14,37
40+		10,84		13,29
0-5		20,94		17,19
5-10		16,99		15,83
10-20	N13	16,53	H13	14,04
20-40		15,44		12,17
40+		10,99		8,29
0-5		17,78		17,86
5-10		18,86		18,73
10-20	N14	15,75	H14	16,55
20-40		11,41		10,09
40+		9,09		7,67
0-5		16,58		16,8
5-10		15,81		16,63
10-20	N15	17,61	H15	18,07
20-40		16,83		13,15
40+		10,57		8,71

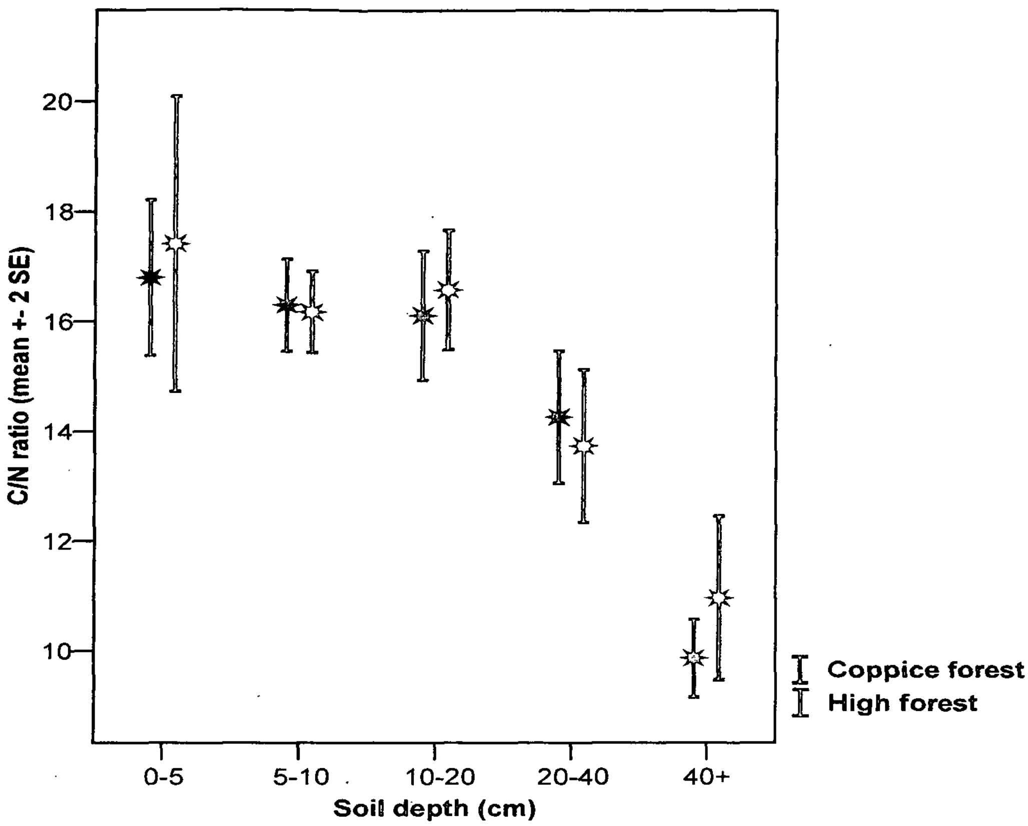


Figure 4.7 C/N ratio (mean ± 2SE) at different soil depth in the high and coppice forest in the Vienna Woods (n=11)

Table 4.20 shows the difference of ration among the different soil depths for the two forest patches.

Table 4.20 ANOVA results for the C/N ratio at different soil depths in the high and coppice forest in the Vienna Woods (*p≤ 0.001, **p≤0.01, *p≤0.05) (n=11)**

		Coppice forest soil depth (cm)					High forest soil depth (cm)				
		0 to 5	5 to 10	10 to 20	20 to 40	40+	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest soil depth (cm)	0 to 5		0,417	0,452	0,019*	0,001***	0,650	0,424	0,807	0,021*	0,001***
	5 to 10	0,417		0,743	0,017*	0,000***	0,452	0,744	0,689	0,030*	0,000***
	10 to 20	0,452	0,743		0,002**	0,000***	0,376	0,922	0,533	0,044*	0,001***
	20 to 40	0,019*	0,017*	0,002**		0,000***	0,074	0,016*	0,010**	0,561	0,013*
	40+	0,001***	0,000***	0,000***	0,000***		0,000***	0,000***	0,000***	0,000***	0,147
High forest soil depth (cm)	0 to 5	0,650	0,452	0,376	0,074	0,000***		0,356	0,528	0,037*	0,002**
	5 to 10	0,424	0,744	0,922	0,016*	0,000***	0,356		0,465	0,022*	0,000***
	10 to 20	0,807	0,689	0,533	0,010**	0,000***	0,528	0,465		0,002**	0,000***
	20 to 40	0,021*	0,030*	0,044*	0,561	0,000***	0,037*	0,022*	0,002**		0,000***
	40+	0,001***	0,000***	0,001***	0,013*	0,147	0,002**	0,000***	0,000***	0,000***	

There is no significant difference in the C/N ratio at all soil depth for the two forest patches (Table 4.21) though we see the C/N ration in high forest is higher than in the coppice forest from Figure 4.7.

Table 4.21 Mean value ± standard errors, ANOVA results for the C/N ratio in the high and coppice forest at different soil depths in the Vienna Woods (*p≤ 0.001, **p≤0.01, *p≤0.05, the same letter are not significantly different at the 0.05 level of significance) (n=11)**

Forest patches	Soil depth (cm)				
	0 to 5	5 to 10	10 to 20	20 to 40	40+
Coppice forest	16,80±0,71[a]	16,29±0,42[a]	16,11±0,60[a]	14,27±0,60[a]	9,87±0,35[a]
High forest	17,41±1,34[a]	16,17±0,40[a]	16,57±0,54[a]	13,74±0,70[a]	10,96±0,75[a]
P	0,691	0,825	0,569	0,574	0,204

5 Discussion

5.1 Ectohumus, root and soil bulk density

The dry mass of ecto-humus is significantly different in the high and coppice forest in the Vienna Woods. Humus is important because it retains moisture in the soil, loosens the soil permitting better aeration and drainage, and encourages the increase of soil organisms which help make nutrients available to plants. It adds body to light soil and loosens heavy, sticky soils. Humus dry mass in the high forest is higher than the coppice forest, probably because of the decomposition of foliage and branch residues in the coppice forest is faster than in the high forest due to the fact that *Carpinus betulus*, *Betula verrucosa*, and other soft leaved species produce litter which is easier to decompose than beech litter. The coppice forest has been used as a source of firewood for a long time. Human activities and harvesting may also increase the decomposition of litter. Cole and Rapp (1981) stated that relatively large quantities of nutrients are stored in the forest floor. I would suggest that the nitrogen and carbon content in the humus should be determined for the further study.

Considering root dry mass in the research area, the coppice forest has more roots at the soil depth 0-5 cm, probably because it is an un-even age forest stands. Coppice forest originating mainly from sprouts or root suckers caused the roots system is much shadow than high forest. This means the root system of coppice forest is not stable comparing with the high forest in the Vienna Woods. Root length is a predominant factor controlling N uptake, and loblolly pine root expansion has been shown to proceed until middle to late summer (Li et al. 1991). The soil roots sampling procedure by soil coring included insufficient samples to proof that the tree in coppice forest has more efficient nutrient uptake than high forest in the research area.

The observed difference of soil bulk density may be caused by the different land use. Abrham (2005) stated that Eucalyptus plantation has higher bulk density than Cupressus plantation and natural forest. Adams (1973) stated that the bulk density of forest soils is generally, closely and inversely related to the organic fraction of the soil. But in this study, the high forest has a higher observed soil bulk density than the coppice. Obviously human activity and harvesting has not strongly affected the soil bulk density in the research area. We considered that the soil root distribution caused the difference.

5.2 Soil acidity

Richter and Markewitz (2001) claimed that soil acidity in turn is a master control of soil fertility and affects many important biogeochemical processes such as rock weathering and nitrification. The entire study region has moderately acidic soils with the mean pH value between 4.76 to 5.21 (Table 4.9). In Europe, forest soil acidification was previously though to be caused by the conifers themselves but has later been ascribed to forest management practices and the continued removal nutrient or the choice of poor sited to grow trees (Innes 1993). But in this study the soil acidity is not caused by the coniferous because there are no conifers in the research area. There is no significant difference of soil pH value between high forest and coppice forest at the soil depth 0 to 20 cm in the Vienna Woods. Michelson et al. (1993) stated that the lower pH value in Eucalyptus man be due to the higher calcium content in the woody biomass and immobilization of higher quantities of base cations with in the woody biomass. I would suggest doing the bulk and clay mineralogical analysis for finding the reason why the soil pH value in the coppice forest is significantly higher than in the high forest at soil depth 20+ cm.

Blay (1989) claimed that with regard to soil acidification and base losses due to acid deposition and nitrification of deposited ammonia it is likely that acidification will diminish soil nitrogen storage capacity and liberate additional nitrogen from soil stores in the Vienna Woods. Since there is no direct link between soil acidity and nitrogen content, I would suggest enlarging the forest patches and soil samples to get more persuadable results.

The exchangeable acidity refers to the amount of H^+ ions on cation exchange sites of negatively charged clay and organic matter fractions of the soil. In this study the active acidity is correlated with exchangeable acidity both in the high and coppice forest (Figure 5.1).

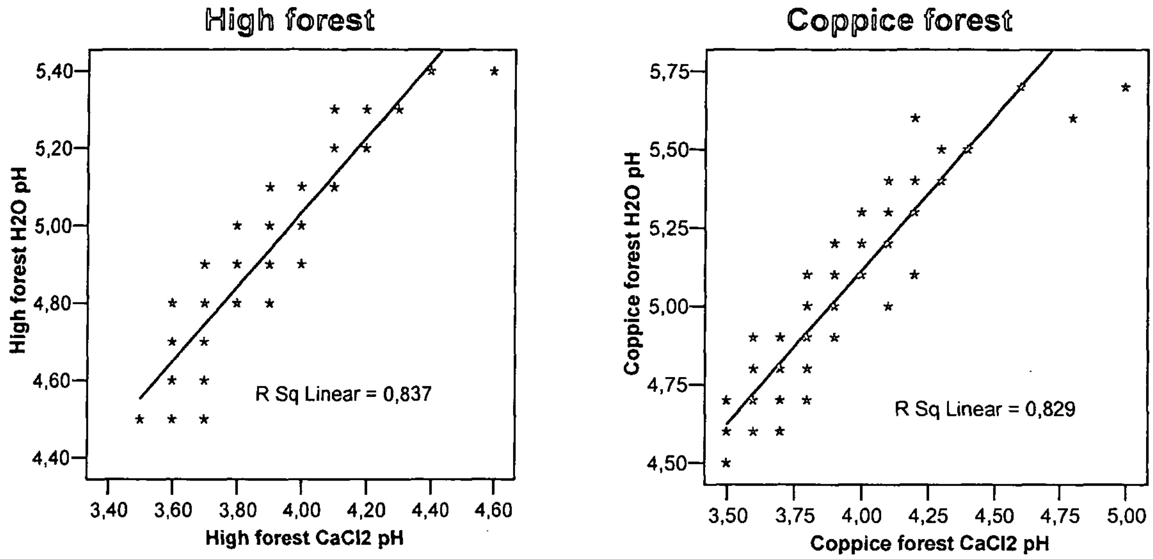


Figure 5.1 Correlation between soil $CaCl_2$ pH value and soils H_2O pH value in the high and coppice forest in the Vienna Woods.

5.3 Nitrogen, Carbon and C/N ratio

Nitrogen is an essential plant nutrient. The total nitrogen content at the soil depth 0 to 5 and 40+ cm are significantly different in the two forest patches. Blay (1989) found that soil nitrogen content varies considerably between beech stands in the Vienna Woods. He also maintained that soil nitrogen depends on the uptake and retention of nitrogen in the biomass and the availability and release pattern of nitrogen in litter. But in this study, the nitrogen content did not vary considerably according to the Table 4.14. One reason for this difference might be the forest stands have changed after 20 years as well as little disturbance since the Vienna Woods became a biodiversity conservation area. There is no possibility to compare the nitrogen content in litter after 20 years. It would be great if the further study continue to analyse the litter nitrogen content for getting a persuadable results,

Leaf tissues are strong sinks for N (Zhang and Allen 1996, Dong et al. 2001), and greater evapotranspiration increases tree N uptake. The soil nitrogen under plantation of pine and poplar, and their neighbouring grasslands in the south-eastern Keerqin region of China has been studied by Chen et al. (2006) and stated that in the grasslands and *Pinus densiflora* plantations have a lower nitrogen content than *Pinus dylestris* var mongolica and *Populus simonii* plantations. In this study, the high forest has more humus but less nitrogen content in the soil. We consider that there more undecomposed foliage residue remains in the high forest and cause the nitrogen content lower and soil observed acidity.

In this study the carbon content in the coppice forest is significantly higher than in the high forest at the soil depth 5 cm. Slope in the coppice forest stand is slightly less than the high forest stands. It is possible that there was less erosion in the coppice stands even though disturbance frequency due to harvesting was much higher. Changes in land management include tillage, practices, nutrient management, and various other factors that sequester carbon (Leifeld et al. 2003). Appropriate nutrient management of soils can reduce the need of adding chemical fertilizer, which in turn may reduce emission. Other land management strategies that fix more carbon in agriculture and forest soils may include employing more perennials, using winter cover cropping, and utilizing erosion control techniques such as terracing, contour plowing, strip cropping, buffer strips and water management (Vleeshouwer and Verhagen 2002). Soil carbon sequestration is considered to be a bridge to the future in controlling increased levels of atmospheric CO_2 until other direct or indirect technologies for its control are developed (Edmonds et al. 1996). In this study we just determined the total carbon content in the two forest patches. The rate of carbon accumulation or loss from soil should be determined by the quantity of recyclable biomass-C, temperature, rainfall, soil moisture content and disturbances for the future study.

Even comparatively less total nitrogen and carbon store is demonstrated in the high forest at the soil depth 5 cm in the Vienna Woods, there is no evidence to show that soil organic matter stores in the coppice forest is higher than in the high forest since we did not analyze and compare the organic matter stores in the Vienna Woods. It is clear that the soil organic matter stores in the coppice forest is higher than in the high forest at the soil depth under the ectohumus in the Vienna Woods.

Doran and Parkin (1996) stated that soil carbon and nitrogen contents and their stocks over the soil profile are considered as indicators of soil quality. Sowden et al. (1977) noted that since 90% of soil nitrogen reserves are organic, the distribution of nitrogen and carbon are usually closely correlated. The correlation of nitrogen with carbon is demonstrated in Figure 5.2. This study has confirmed that nitrogen and carbon are highly positively correlated both in high and coppice forest in the Vienna

Woods. Figure 5.3 shows the correlation among carbon, nitrogen, H_2O pH value and $CaCl_2$ pH value in the coppice and high forest. Figure 5.4 shows the correlation among carbon, nitrogen, H_2O pH value and $CaCl_2$ pH value in entire research area. It is evident that nitrogen and carbon stores in the soil are not or possibly only very weakly correlated with soil acidity under the conditions encountered in the investigated stands.

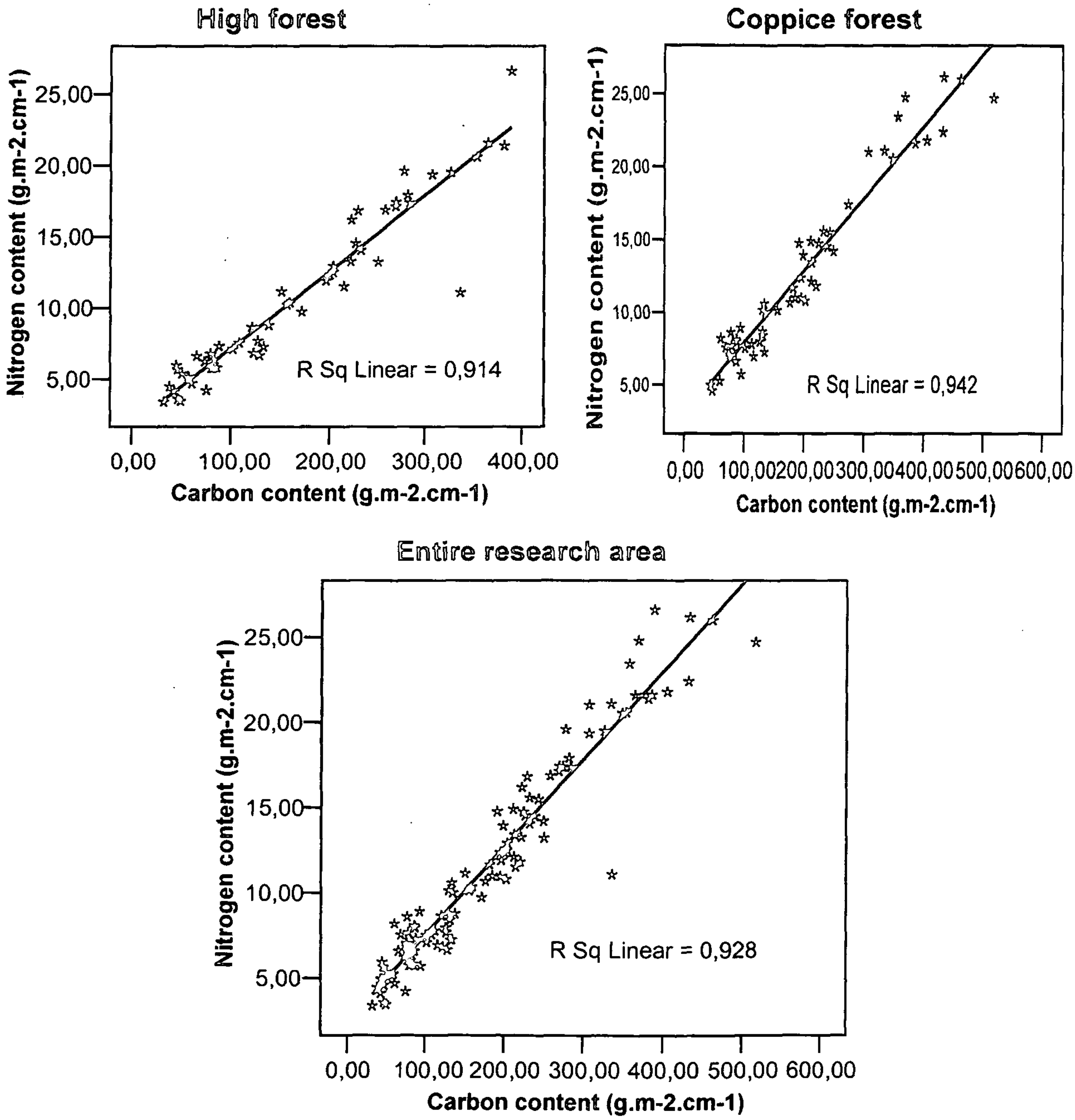
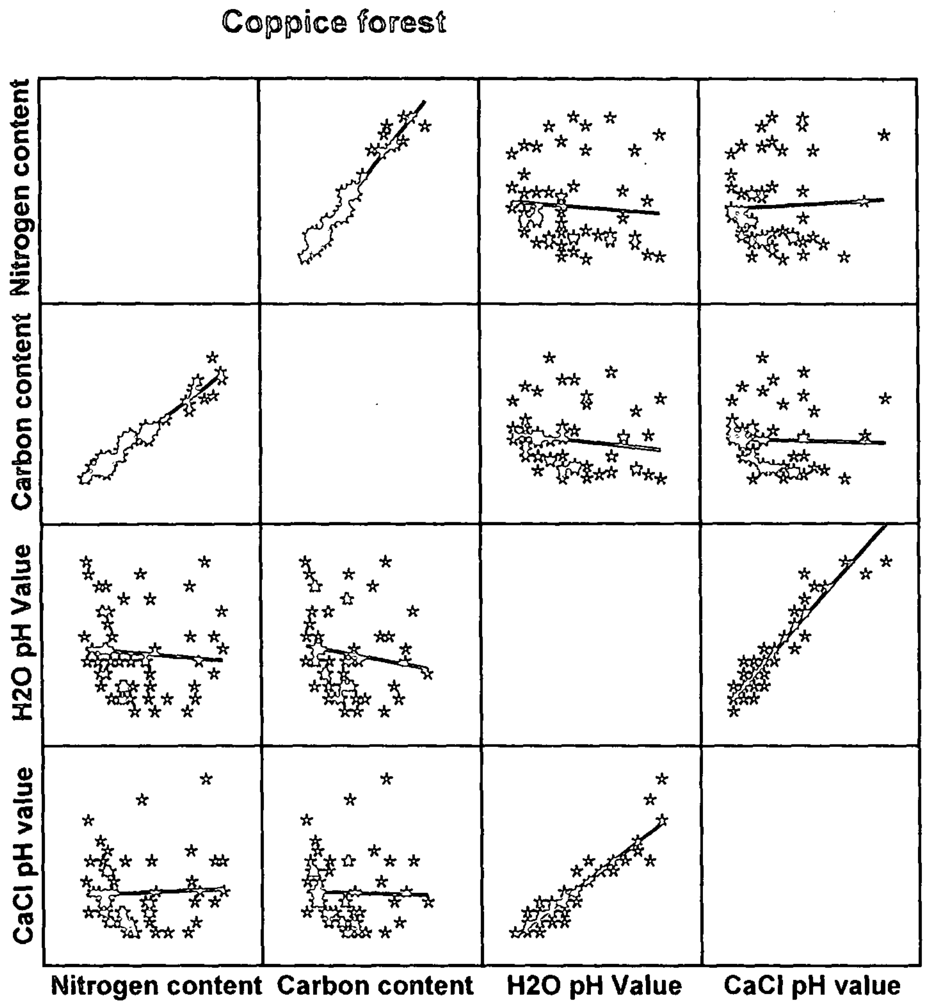


Figure 5.2 Correlation between nitrogen content ($g.m^{-2}.cm^{-1}$) and carbon content ($g.m^{-2}.cm^{-1}$) of soils in high and coppice forest in the Vienna Woods



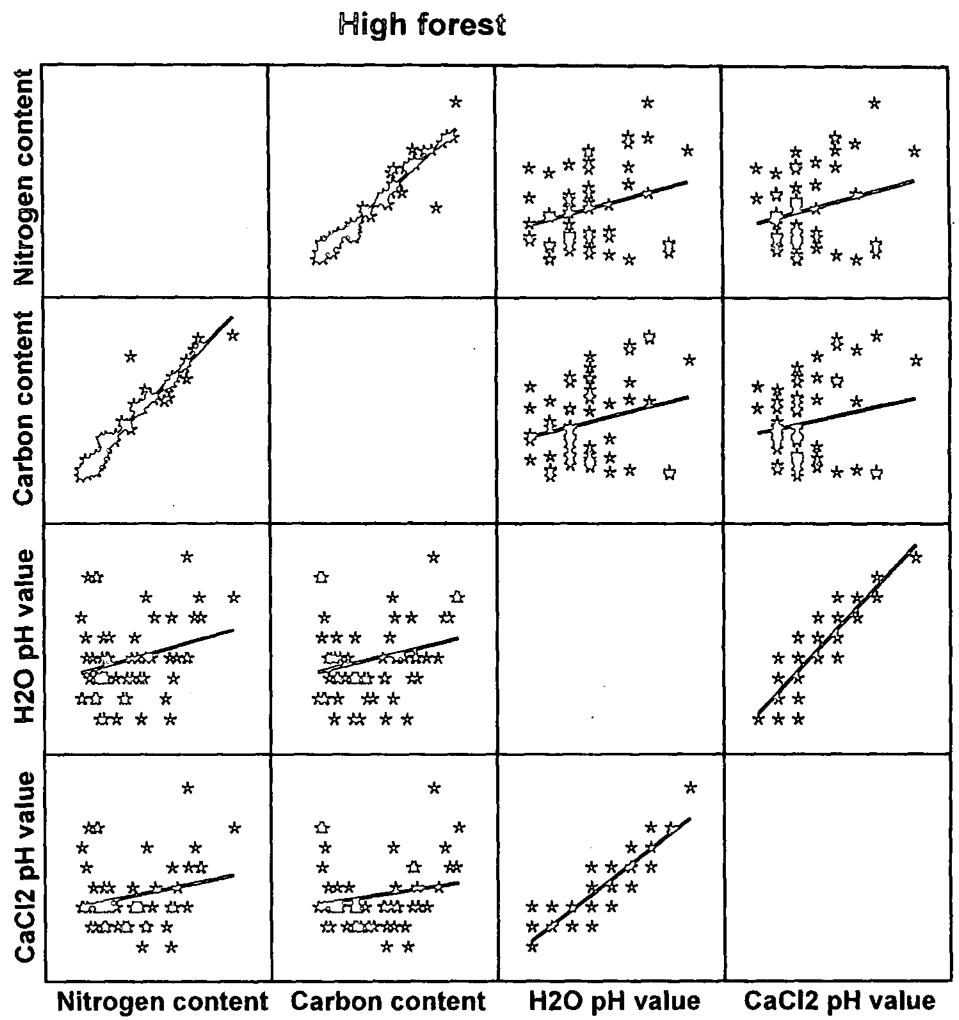


Figure 5.3 Correlation among nitrogen, carbon, H_2O pH value and $CaCl_2$ pH value in the coppice and high forest in the Vienna Woods

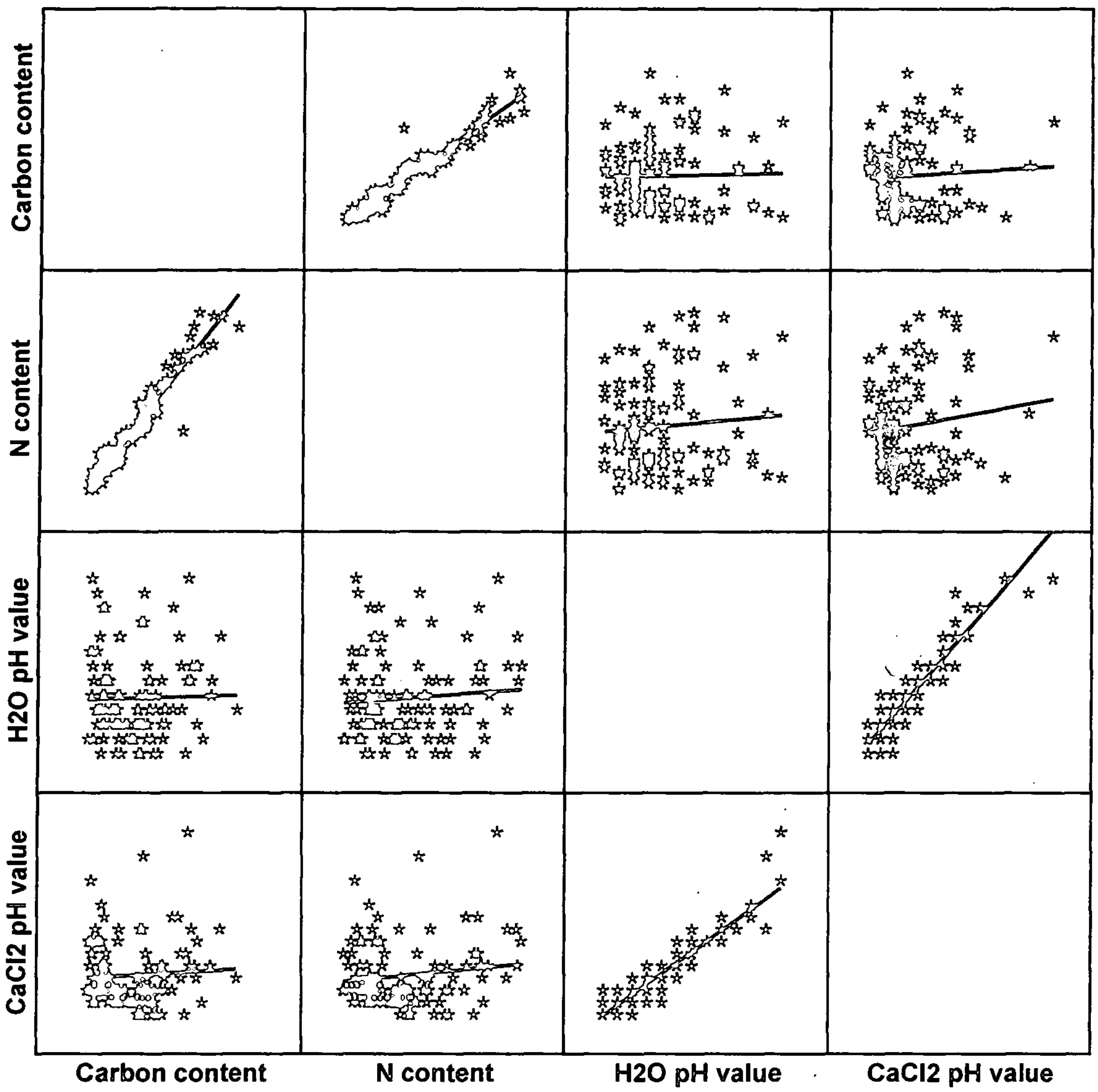


Figure 5.4 Correlation among carbon, nitrogen, H_2O pH value and $CaCl_2$ pH value in the entire research area

Nitrogen is liberated from organic materials in a process (mineralization), but it becomes available to higher plants only as the C/N ratio approaches 10:1. During the mineralization of carbonaceous materials such as forest floor litter, the C/N ratio decreases with time (Alexander 1997). Fisher and Binkley (1999) stated that 95% of nitrogen in surface soil is found in the soil organic matter and hence there is a positive correlation. The amount of organic matter and nitrogen in the soil at any given time depends on many climatic and edaphic factors, as well as natural or human disturbances that influence the ratio of plant and animal additions to the rate of decomposition. Camberato (2001) claimed that the readiness of nitrogen mineralization from organic compounds is a function of C/N ratio. Less than 15:1, the nitrogen content is relatively high and the microorganisms rapidly release nitrogen when they decompose the material. When the ratio is greater than 30:1, it indicates low nitrogen content. In order for the organism to break down a high C/N material, then inorganic material is removed from the soil solution.

In this study, the mean value of C/N ratio in the coppice forest is 16.80 at soil depth 0 to 5 cm, 16.29 at soil depth 5 to 10 cm, 16.11 at soil depth 10 to 20 cm, 14.27 at soil depth 20 to 40 cm and 9.87 at soil depth 40+ cm. The Mean value of C/N ratio in the high forest is 17.41 at soil depth 0 to 5 cm, 16.17 at soil depth 5 to 10 cm, 16.57 at soil depth 10 to 20 cm, 13.74 at soil depth 20 to 40 cm and 10.96 at soil depth 40+ cm (Table 4.20). There is no significant difference between two forest stands in the research area. This C/N ratio indicates the decomposition of litter is under good condition in the Vienna Woods.

6 Conclusion

This study was conducted to establish a primary dataset of humus dry mass, tree root biomass, soil properties, nitrogen and carbon accumulation in the high and coppice forest within the Vienna Woods.

This study has demonstrated that ectohumus dry mass in the high forest is significantly higher than in the coppice forest in the Vienna Woods. In the uppermost soil horizon (0 to 5 cm) root mass in the coppice forest is significantly higher than the high forest. No significant difference of root dry mass at the soil depth 5 to 40+ cm between the high and coppice forest in the Vienna Woods could be detected but it has to be noted that 15 soil cores per plot allows only a very rough assessment.

Soil bulk density was lower in the coppice forest, most likely due to better biological activity in the more tree species diverse coppiced forest. The soil bulk density is significantly increasing with the increase of soil depth both in the high and coppice forest in the Vienna Woods.

This study has confirmed that the entire study area has moderately acidic soils with the mean H_2O pH value between 4.76 to 4.96 in the high forest and mean H_2O pH value between 4.91 to 5.21 in the coppice forest. The entire study area has a mean pH range for the exchangeable acidity from 3.72 to 3.97 in the high forest and 3.80 to 4.06 in the coppice forest. There is no significant difference of soil H_2O pH value at soil depth 0 to 20 cm between the high and coppice forest in the Vienna Woods. In the coppice forest the soil H_2O pH value is significantly higher than the high forest at the soil depth 20 to 40+ cm, which might indicate slight differences in the parent material.

In this study we sought to examine the nitrogen and carbon content as well as the correlation between them in the high and coppice forest within the Vienna Woods.

The nitrogen content in the high forest is 18.35 $g.m^{-2}.cm^{-1}$ at soil depth 0 to 5 cm, 14.97 $g.m^{-2}.cm^{-1}$ at 5 to 10 cm, 11.06 $g.m^{-2}.cm^{-1}$ at 10 to 20 cm, 7.01 $g.m^{-2}.cm^{-1}$ at 20 to 40 cm and 5.46 $g.m^{-2}.cm^{-1}$ at 40+ cm. The nitrogen content in the coppice is 22.43 $g.m^{-2}.cm^{-1}$ at soil depth 0 to 5 cm, 13.83 $g.m^{-2}.cm^{-1}$ at 5 to 10 cm, 11.54 $g.m^{-2}.cm^{-1}$ at 10 to 20 cm, 7.87 $g.m^{-2}.cm^{-1}$ at 20 to 40 cm and 6.79 $g.m^{-2}.cm^{-1}$ at 40+

cm. The nitrogen content in the coppice forest is significantly higher than in the high forest at soil depth 0 to 5 cm and 40+ cm.

The carbon content in the high forest is 305.06 $g.m^{-2}.cm^{-1}$ at soil depth 0 to 5 cm, 238.14 $g.m^{-2}.cm^{-1}$ at 5 to 10 cm, 159.60 $g.m^{-2}.cm^{-1}$ at 10 to 20 cm, 94.12 $g.m^{-2}.cm^{-1}$ at 20 to 40 cm and 53.15 $g.m^{-2}.cm^{-1}$ at 40+ cm. The carbon content in the coppice forest is 381.94 $g.m^{-2}.cm^{-1}$ at soil depth 0 to 5 cm, 233.95 $g.m^{-2}.cm^{-1}$ at 5 to 10 cm, 180.37 $g.m^{-2}.cm^{-1}$ at 10 to 20 cm, 111.74 $g.m^{-2}.cm^{-1}$ at 20 to 40 cm and 67.93 $g.m^{-2}.cm^{-1}$ at 40+ cm. There is a significant difference of soil carbon content at soil depth 0 to 5 cm between high and coppice forest in the Vienna Woods.

This study has also confirmed that there is a high positive correlation of the total nitrogen content and carbon content both in the high and coppice forest. Nitrogen and carbon stores in the soil are not or possibly only very weakly correlated with soil acidity under the conditions encountered in the investigated stands. Comparatively less total nitrogen and carbon stores is demonstrated in the high forest in the Vienna Woods. The soil organic matter stores in the coppice forest is higher than in the high forest at soil depth under ectohumus in the Vienna Woods.

There is no significant difference of C/N ratio between high and coppice forest in the Vienna Woods. The mean value of C/N ratio is 16.80, 16.29, 16.11, 14.27, and 9.87 at soil depth 0 to 5, 5 to 10, 10 to 20, 20 to 40, and 40+ cm in the coppice forest in the Vienna Woods. The mean value of C/N ratio is 17.41, 16.17, 16.57, 13.74, and 10.96 at soil depth 0 to 5, 5 to 10, 10 to 20, 20 to 40, and 40+ cm in the high forest in the Vienna Woods.

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