Mendel University in Brno

Faculty of Forestry and Wood Technology

Department of Geology and Pedology

Comparison of selected soils on glacifluvial parent material in Poland and the Czech Republic

Diploma thesis

2016

Bc. Ondřej Bešťák

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Faculty of Forestry and Wood Technology

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DIPLOMA THESIS TOPIC

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Guides to writing a thesis:

1. To evaluate the available literature on the issue of the soils on glacifluvial and glacilacustrine sediments, their occurence and use in Poland and the Czech Republic
2. Select suitable localities (5-6) in Poland, dig soil pits, describe them and do site evaluation, including photodocumentation, take soil samples and analyze them
3. Compare the results with selected soil profiles from Northen Moravia, evaluate field conditions and selected physical and chemical properties of soil
4. Compare importance and use of the soils in Poland and the Czech Republic, evaluation in relation to landscape management (agriculture and forestry)
5. The results document graphically and in tabular

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Bc. Ondřej Bešťák
Author of thesis

doc. Mgr. Aleš Bajer, Ph.D.
Thesis supervisor

prof. Ing. Klement Rejšek, CSc.
Head of Institute

doc. Ing. Radomír Klvač, Ph.D.
Dean FFWT MENDELU

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Abstrakt

Práce je zaměřena na porovnání vlastností půd na glaciofluviálním sedimentu v Polsku a České Republice. Byly sledovány jejich fyzikální, chemické a biochemické vlastnosti. Vzorky byly odebrány na pozemcích s rozdílným využitím a v různou roční dobu. Následně byly převezeny do laboratoře LDF Mendelu, ústavu Geologie a Pedologie, kde byly následně analyzovány. Výsledky prokázaly, že odebrané vzorky z jednotlivých půdních profilů jsou složeny převážně z 85 – 95% z písčitých frakcí (2 – 0,05 mm) se zanedbatelným podílem štěrků, spraší a jílů. Hodnoty při stanovení půdní reakce poukázaly na fakt, že půdy jsou velmi kyselé s výjimkou profilů 4 a 5, kde půdní reakce byly popsána jako alkalická. Při stanovené enzymatické aktivity v půdách bylo zjištěno, že aktivita půdní fosfatázy, ureázy klesá se vzrůstající hloubkou. Analýza mikrobiálního uhlíku v profilech 3 a 4 odhalila zvýšené množství uhlíku v nejhlubší vrstvě profilu.

Klíčová slova: Arenosoly, Glacifluviální materiál, Půdní klasifikace, Vlastnosti půdy

Abstract

The aim of this thesis was to compare properties of the soils on glaciofluvial sediment in Poland and the Czech Republic. Physical, chemical and biochemical properties were monitored in soil profiles. Samples were collected on lands with different land use and in different time of year. Subsequently, samples were transported to the laboratory of Faculty of Forestry and Wood technology at Mendel University in Brno, Department of Geology and Pedology, where soils were analyzed. The results showed that samples taken from various soil profiles are mainly composed from 85-95% of the sandy fraction (2 - 0.05mm) with a negligible proportion of gravel, loess and clay particles. Determined values of soil reaction reflected the fact that the soil is very acidic, within profiles no. 4 and 5, where soil reactions were described as slightly alkaline. When enzymatic activity of soil was determined, it was found that the activity of soil phosphatises and ureases decreases with soil depth. C_{mic} analyse exhibits decreasing trend in profiles no. 1, 2, 5 and 6. On the other hand, the higher amount of microbial carbon was found in deepest layers of profiles no. 3 and 4.

Key words: Arenosols, Glacifluvial material, Soil classification, Soil Properties

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Table of abbreviations

BPEJ – Estimated pedological ecological unit

C_{mic} – Soil microbial carbon

DM – Dry mass

LPIS – Public register of soils

MZe – Ministry of Agriculture of Czech Republic

SgP – Polish soil classification system

TKSP – Czech soil taxonomical classification system

TOC – Total carbon content

WRB – World reference base

1.Introduction

In course of last 2.4 million years, some parts of Europe were affected by glacier coming from North Europe. There were eight glacial and interglacial periods in Poland. In Czech Republic, glacier occurred only twice. When glacier moved, parent rock (mainly granite or other acidic rocks) was mechanically weathered into sandy particles which are typical for glaciofluvial soils. Ice had a major role in landscape formation, transportation and accumulation of material in layers as well. Landscape was formed of sandy soil formations, glacier lakes, moraines etc. Rivers originating from melted ice transported a lot of material for long distances. Material sedimented in layers and sandy terraces were formed. Soils, which occur on this material, have specific granulometrical content, chemical and biochemical properties. Sand is formed from acidic components which cause that soil reaction becomes very acid.

Landscape colonization by people started after deglaciation. Landscape of Czech Republic was colonized firstly because glacier covered Poland yet. People started to cultivate soil for plant cultivation and livestock breeding. However, people were moving into coastal regions, where they found to favourable conditions for agriculture as well. Proximity to the sea also allowed them to hunt marine animals and trade between distant countries other than the overland route. Since that period, people development increased. Therefore, arable land should increase as well. People needed to cultivate a crop on larger field but they found that some soils are not as fertile as they though. Soils were very sandy without organic material, arid with low enzymatic activity. Therefore, they tried to find some cultivation methods how to increase amount of organic compounds in soil. Using an animal manure and green fertilizers was the best option to create a suitable conditions for soil living organisms. Under more suitable conditions, soil organisms start to decompose these organic compounds to produce nutrition for plants.

Thesis was based on studying of selected soils of different using on glaciofluvial parent material during study program in Poznań.

2. Thesis objective

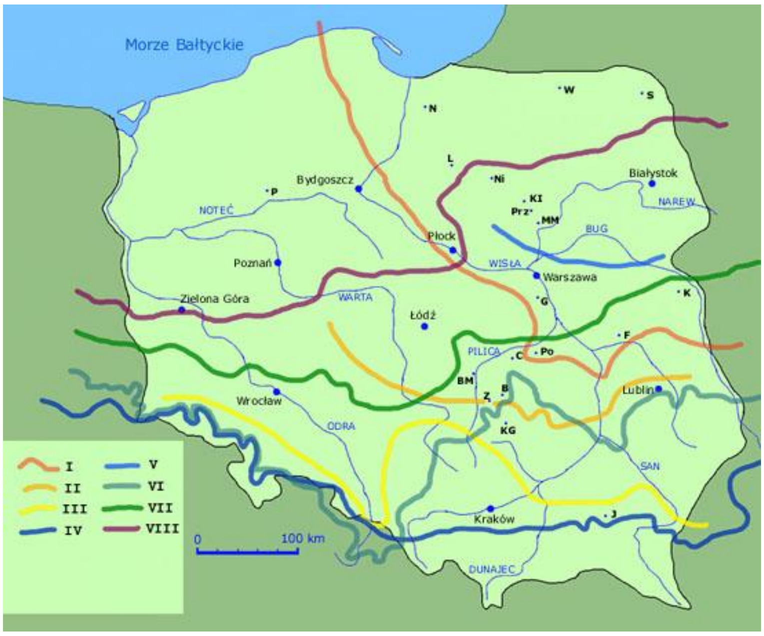
The aim of diploma thesis is comparison of soils on glaciofluvial parent material in Poland and Czech Republic according to their biochemical and physical properties (granulometry, soil reaction and microbial carbon content) and land use (cultivated or forest areas) of studied soils in relations to Czech and Polish classification system.

3. POLAND

3.1. Pleistocene and glacial period in Poland

During Pleistocene whole Poland was located permanently between glacial and interglacial periods. However, chronology of Pleistocene glaciations in Poland and Europe is not clearly defined: Lindner (1992), Mizerski and Orłowski (2005). These periods were caused by Scandinavian glacier what covered a polish area for last 1000 years of glacial period. During Pre – Pleistocene era climate condition started to be colder and the first glaciations appeared at the beginning of Pleistocene, almost 1.2 million years ago. However glaciers have shown their power on soil sedimentation, smoothed rocks and their impact may be seen in the Earth where glacier occured. Also it was not single evidence in Earth's history. That´s a reason why Dzięciołowski (1978) thinks, that this situation is due to occur again.

Although this situation could recurre, Pleistocene glaciation is good to introduce. Because ice had caused a smoothing of Poland and it has affected a soil development. Figure no. 1, represents the reach of glacier in Poland, which confirms why soils in Poland. There are 8 periods of glacial activity distinguishable in last million years.



Picture no. 1, **Terminal ridges of pleistocenic glaciations**

Explanations: I. Günz glaciation, II. Mindel I glaciation, III. Mindel II, IV. Mindel glaciation, V. Mindel - Riss glaciation, VI. Riss I glaciation, VII. Riss II glaciation and VIII. Wurm glaciation; positions of interglacial periods (sediments): Podlaski (KI –

Kijewice, C – Ceteń), Małopolski (KG – Kozi Grzbiet, PRZ – Przasnysz), Ferdynandowski (Po – Podgórze), Mazowiecki (BM – Barkowice Mokre, MM – Maków Mazowiecki), Zbójna (Z – Zbójno), Lubawski (L – Losy) and Eemski (B – Bedlno, P – Piła)

Source: http://www.geopasja.pl/teoria/geo_czwartorzed.htm, author Lindner (1992)

Polish Chronology of glaciations

In the beginning of glacial period climate conditions changed almost every hundred years. Glacier proceeded always from north from Scandinavia, but some relicts of Pleistocene glaciations may be found on Iceland. In Poland was eight glacial and interglacial periods. All of them are presented in Table no. 1, which shows occurence of individual periods.

The first and the oldest epoch of glaciations in Poland was **Narwa**. Fragments which were preserved to present in northeast part of Poland and are not identified well. Soil created on post Narwa glaciations are presented by the *gliny zwalowe*, which may be found together with thin layer of glaciofluvial sediments. Thickness of deposits may be from several centimetres to several metres. After hundred thousand years where Podlaski interglacial brought a warmer climate, the Southern Poland glaciations came. This era included three main periods called **Nidy, San I and San II.** Glacial effects are observable mainly in Central and Northern part of Poland where sediments were accumulated under Quaternary soils body. Relicts of this glacial epoch mostly consist of sands and fluvioglacial gravels as well as clays. Next most important period in history of Poland Pleistocene was **Mazowiecki interglacial**. During this interglacial water erosion increased in intensity and landscape-forming impact. Due to erosion the river valleys occurred and covered by alluvial material. Moreover, peatbogs has been created in this time. It continued several tens of thousands years and the climate was changed again by **Liwca glaciations,** Mizerski (2012).

Together with Mazowiecki interglacial and Zbójnowski interglacial is this period named Great interglacial. Following glaciations were called **Odra and Warta**. Their impact on soil development was relatively unimportant. For example Mizerski and Orłowski (2005) stated that "Maximal area covered by ice was during Odra one where glacier leaned against Sudeten, while polish highlands in Central part of Poland were not covered with ice. Soils originating in this era are represented by bouldery clays and fluvioglacial detritus. Also Glacier valleys and loess have been created in the foreland of glacier sheet”.

Consecutively, according to Mizerski (2012), the major influence on polish soil bodies exhibited **Wisła glaciations**. There are various examples of ice phenomena like moraines etc. which are preserved until today. Also river sedimentation and erosion occurence is documented as well.

Table no.1, **Overview of glacial and interglacial periods in Poland and The Alps**

Poland				**Alps**
Stratigraphy	Time*	Glacial and interglacial periods		
Holocene	0			
Upper Pleistocene	100	Glaciation of Northern Poland	Wisla glaciation	Würm
			Eemski interglacial	Riss II - Würm
Middle Pleistocene	200		Warta glaciation	Riss II
		Middle Poland glaciation	Lubawski interglacial	Riss I - Riss II
			Odra glaciation	Riss I
	300	Great interglacial	Zbójna integlacial	Mindel - Riss
	400		Liwca glaciation	
			Mazowiecki interglacial	
	500	Southern Poland glaciation	San II glaciation	Mindel III
			Ferdynandowski interglacial	Mindel II - Mindel III
	600		San I glaciation	Mindel II
			Małopolski interglacial	Mindel I - Mindel II
	700		Nida glaciation	Mindel I
Lower Pleistocene	800		Podlaski interglacial	Günz - Mindel I
	900		Narwa glaciation	Günz
Pre-Pleistocene	1 870		Celestynowa interglacial	Donau - Günz
			Otwocka glaciation	Donau
	2 480		Ponurzycy interglacial	
Pliocene				

Exlanations: * Time in thousands years

3.2. Glacial and fluvioglacial erosion

In glacial period entire polish landscape was covered by ice. Due to its movement there are glacial formations caused by glacial and fluvioglacial erosion in Poland. Their impact on polish environment is still actually. As Mizerski (2003) reported, glacier consisted of big amounts of rock material which was plucked from bedrock and encased into glacier body. This type of erosion is called plucking. Other types of mechanical glacial erosion are defined like abrasion and freeze thaw. During interglaciation era glacier melt and created, like Koćmit et al., (1997) written, huge rivers whose streams transported great bulk of of rock materials. Formerly encased in glacier and deposited it in distance area. As melted water flowed through glacier mass, pressure of water turbulence abraded a bedrockand glacier mills appeared. Concurrently Mizerski (2006) described erosion by water melted from glacier. Waters coming from melted ice are called fluvioglacial waters (in polish language wody rzecznolodowcowe). Differences between water erosion of river streams and glacial water is that water in rivers flows only under the influence of gravity but water form melting ice flows under the ice pressure.

3.3. Glacial and fluvioglacial accumulation

Glacier did not cause only erosion. It transported rock material for several hundred kilometres. Moreover, when ice moved it pushed a huge amount of material ahead and after it´s melting a moraines have been formed. Moraine formation is a sedimented non-assorted material. It´s divided into several types as Lateral, Medial, Terminal and ground moraine Mizerski (2006).

Special formation of glacial accumulation is called **drumlin.** According to Spagnolo et al., (2014) is defined as oval-shaped hills that are found in terrains formerly occupied by an ice sheet and whose shape is aligned in the direction of ice flow. Despite most drumlins being characterized by a similar, typical shape, their structure and internal composition is found to be diverse and includes at least three end members: bedrock-cored, till, and stratified sediments

Glacier has an important role in material accumulation. In this case, transport of material is replaced by water from melting ice called like fluvioglacial one. As Bednarek and Prusinkiewicz (1999) defined this fluvioglacial material consists of sands with different grains size and mixed with gravel. This material was carried by water underneath a glacier and transported to distant areas, where it sedimented in layers. In front of terminal moraines **sandrs** formations are created, typically composed of sand and gravel.

In contrast, behind terminal moraine the crumbled rock material was carried exclusively by flowing water and new waterways were formed, creating new sedimentary formations along the way. Mizerski (2006) divides these formations to several forms: esker, kames, glacier eyes and kame terrace

Eskers occur when waterway is blocked under glacier body. A river basin can be blocked by gravel or sand and river creates new bed. When glacier receded, sedimentary long sandy walls emerge. Formation similar to esker is **kame**. The term denotes smaller hills formed by interlayering sands and gravels. It has been created in open glacier slits when glacier remained in place or disintegrated to smaller separated glacier eyes called **glasses of dead ice**. Between a glacial edge or glasses are created forms called **kame terrace**. Kame terrace, according to Bitinas et al. (2004), is defined as a "terrace-shaped ridge formed by stratified sand and gravel layers and resulting from ice meltwater sediments accumulated between the melting glacier or dead ice blocks and the higher slope of the glacier valley or lateral moraine"

3.4. Soils on glaciofluvial parent material

As it mentioned above, whole Poland was under influence of ice for last 2.48 million years. In that period a huge amount of heterogeneous material was transported and sedimented in entire polish area. According to Marcinek (2008) these soils, occurred after recession of glacierconsists of gravel of various grain-size. Mineral composition of these soils is mainly quartz, additional amount of feldspar and mica and a minor amount of clay material. Fluvioglacial material is a basic component forming soils categorized to **arenosols, podzols, fluvisols and gleysols.** (gleby rdzawoziemne, bielicoziemne, plowoziemne i murszaste). These soils will be described further.

3.4.1. Arenosols

Arenosols are young soils, weakly developed and created mainly from unconsolidated sands of different grain-size and different chemical reaction – from neutral to acidic. Characteristic sign of these soils is stratigraphy with onyl A and C horizons present. Thickness of accumulated A horizon is usually from 10 to 30 cm while C horizon may be from 30 to 150 cm deep. Fertility of soil depends on soil moisture, quantity of humus or mineral composition and physical soil properties. In natura, its occurrence is connected with forests, mainly pine forest, weakly on mixing pine forest with other tree species and sporadically on mixed one. Its occurrence in polish land is about 14%.

Most notable subgroups present in Poland are: albic arenosol, brunic and rubic one. Defined by Bialy et al., (2000)

3.4.2. Podzols

These soils, as Zawadski (2002) defines, consist of mineral particles of different origin, weak in nutrienss and mainly formed by podzolisation process. Podzol reported by Borger et al. (2014) summarized the basic ideas of podzolisation: *mobilization–downward transport–immobilization* of Al and Fe. Podzols defined by Lundström et al. (2012) occur mainly in cool humid climates under forest or heath vegetation in medium textured to coarse material, where conditions favour the development of an organic surface (mor) layer. Below the mor layer is an ash-grey, weathered eluvial horizon (E), which contains less base cations, Al and Fe than the parent material and is enriched in residual Si. This horizon is in turn underlain by a dark coloured (reddish-brown, dark brown, black) illuvial horizon (B) enriched in Al, Fe and organics. However, the illuvial horizon in podzols where the ground water table is high do not enrich Fe, probably because Fe is reduced. Below the B horizon is the C horizon that shows relatively little signs of soil formation. Zadawski (2002) also states that this type of soil is reported at 10% of polish area.

3.4.3. Gleysols

Gleysols comprise soils saturated with groundwater for long enough periods to develop reducing conditions resulting in gleyic properties, including underwater and tidal soils. This pattern is essentially made up of reddish, brownish or yellowish colours at aggregate surfaces and/or in the upper soil layers, in combination with greyish/bluish colours inside the aggregates and/or deeper in the soil. Gleysols with a thionic horizon or hypersulfidic material (acid sulfate soils) are common. Redox processes may also be caused by upmoving gases, like CO_2 or CH_4. Common names for many Gleysols are Gley (former Soviet Union), Gleyzems (Russia), Gleye, Marschen, Watten and Unterwasserböden (Germany), Gleissolos (Brazil) and Hydrosols (Australia). In the United States of America many Gleysols belong to Aquic Suborders and Endoaquic Great Groups of various Orders (Aqualfs, Aquents, Aquepts, Aquolls, etc.) or to the Wassents FAO (2014).

3.4.4. Fluvisols

Fluvisols accommodate genetically young soils in fluvial, lacustrine or marine deposits. Despite their name, Fluvisols are not restricted to river sediments (Latin fluvius, river); they also occur in lacustrine and marine deposits FAO (2014). Chesworth (2008) wrote:´´Fluvisols are young soils, formed on recent sediments, and showing evidence of stratification. Texture ranges from coarse sand to heavy clay. They are formed in environments prone to the addition of sediment during flooding events. They are commonly stratified, and the distribution of organic matter in the solum may be irregular. Where the soil material has the texture of sandy loam or finer, a cambic subsurface horizon will form and the Fluvisol will grade into a Cambisol, provided that the solum is not water saturated. In the latter case, redox reactions will convert the Fluvisol into a Gleysol´´.

3.5. Land use in Poland

In previous chapters information relevant to land use classification in forests and arable lands was discussed. As classification shows, the major part of Poland is characteristic with soils of poor fertility, belonging to IV., V. and VI. category in agricultural use suitability with low potential for cultivationand similar bonitation classes in forest stand. Following chapters describe suitability of discussed soils for agricultural and forestry use.

3.5.1. Forestry

As Forestry company in Poland (Lasy Państwowe) stated in their annual report from 2013, the forest land encompass 9 177 200 hectares; its equal to 29, 4 % of polish area which is calculated from 31 267 900 hectares of total area. In Poland it is possible to find many forest habitats under influence of glaciafluvial or glacilacustrine parent material. Jaszczak and Magnuski, (2012) determined and described forest types as dry pine forest (DPf) , fresh pine forest (FPf), moist pine forest (MPf), mixed fresh pine forest (MFPf), mixed moist pine forest (MMPf), mixed fresh forest (MFf) and mixed moist forest (MMf).

Occurrence of **dry, fresh and moist pine forests** is closely realted to lowlands with poor mineral composition and low fertility. Their bedrock composition consists mainly of sands originating from glacifluvial, rivular, marine and sanders formations. Soil types under these forests are mainly leptosols, arenosols, podzols and gleysols. Due to specific conditions the tree composition of first floor consists of Pine (*Pinus sylvestris*), Birch (*Betula pendula*) and rarely Spruce (*Picea abies*). At locations with sufficient water availability Alder (*Alnus glutinosa*) and Rowan (*Sorbus aucuparia*) can be found.

Comparatively opposite conditions apply in **mixed fresh pine forest and mixed moist pine forest**. They have better conditions than pure pine forest stands because water availability is higher than in previously discussed locations. Common soil types are dystric arenosols, brunis arenosols, podzols and gleyc podzols. Tree composition incorporates Pinus (*P.sylvestris*) and Spruce (*P.abies*). Associated species may be represented by Beech (*F.sylvatica*), Oak (*Quercus sp.*), Larch (*Larix decidua*), Birch (*Betula sp.*), Linden (*Tilia cordata*) and Hornbeam (*Carpinus betulus*). In mixed moist pine forest Fir (*Abies alba*) adds as well. Sometimes it is possible to find rare European pear (*Pyrus communis*).

Mixed fresh forest and mixed moist forest show more favourable conditions. They are forming habitats with moderate fertile mineral composition which are close to natural or only marginally altered conditions. Also they may be subjected to influence of ground water. Soils of these sites are described like Brunic Arenosols, Luvisols, Gleysols, or Gleyc Cambisols. Stand composition is similar to Mixed pine forests.

3.5.1.1. Classification polish soils under forest stands

In accordance with article 20, paragraph 3 of the Act of 17th may 1989 – Geodetical and cartographical law (Dz. U. from 2005 no 240, poz. 2027) all arable and forest land must be classified under soil classification. Mocek (2015) described some typological soil types under forest stands (table no. 2).

Tab. no 2, **Tree composition** according to Haze (2012), who recommended a planting percentage of tree species.

Forest habitats	Main trees species	Associated trees species	Supported trees species	Examples of trees plantation (%)
DPf	P	Brch		P 90, Brch 10
FPf	P	Brch	Adr, EMA	P 80-90, Brch and rest 10-20
MPf	P	Sce, Brch	Adr	P 80, Sce and rest 20
	P, Sce	Brch	Adr	P 60, Sce 30, Brch 10
MFPf	P	Okr., Bch, Brch, Lrx	Acr, Lnd, EMA, Hrb	P 80, Okr and rest 20
	OKr., P	Bch,Brch,Lrx	Acr, Lnd, EMA, Hrb	P 70, Okr 20, Bch and rest 10
MMPf	P	Okr, Sce, Brch	Acr, Lnd, Adr	P 70, Okr and rest 30
	P, Sce, Brch	Okr	Acr, Lnd, Adr	Brch 50, Sce 20, P 20, Okr 10
	Sce, P	Okr, Brch	Adr, Acr, Lnd	P 50, Sce 30, Okr and rest 20
MFf	Bch, P	Okr, Lrx, DglF, Brch	Hrb, Acr, Lnd,Apt,Pr	P 50, Bch 30, Okr and rest 20
	P, Okr	Bch,Brch,Lrx, DglF	Acr, Hrb, Lnd,Apt,Pr	Okr 50, P 30, Bch and rest 20
	Brch, Sce, Okr	P, Lnd	Hrb, Acr, Apt, Pr	Okr 40, Sce 30, Brch 20, P 10
	OKr., P	Bch, Hrb, Lrx, DglF	Ppl	P 50, Okr 30, Bch and rest 20
MMf	P, Okr	Sce, Brch, Bch, Acr	Adr, Brch, Lnd	Okr 50, P 30, Sce and rest 20

*Legend: (Pinus) **P**, (Spruce) **Sce,** (Larix) **Lrx,** (Douglas fir) **Dglf,** (Oak) **Okr,** (Birch) **Brch,** (Beech) **Bch**, (Linden) **Lnd**, (Hornbeam) **Hrb**, (Acer) **Acr**, (Alder) **Adr**, (European mountain ash) **EMA**, (European pear) **Pr**, (Populus) **Ppl**.

3.5.2. Agriculture

Soil classification under arable land is focused on using soils like a source for producing of agricultural commodities mainly crops and food. However, soils have to meet certain criteria for inclusion to distinctive classification levels. Bonitation according to Mocek (2010) and Falkowski, Kostrowicki (2001) depends on these criteria:

1) Granulometrical composition

2) Depth of humus horizon and its quantity

3) Structure

4) Water conditions

5) pH and calcium carbonate occurrence

6) Landscape topography etc.

According to these conditions, the soils are divided into groups identified by I, II, IIIa, IIIb, IVa, IVb, V and VI. Sometimes, classes identified like IIIa and IIIb or IVa and IVb are incorrectly included like subclasses III and IV.

Class I. Soils best arable

The soils are located in most favourable physiographical conditions, mainly in lowlands or on very gentle slopes. They contain all necessary nutrients have a good natural structure in whole profile, easily arable and warm. These soils are best suitable for sugar beet, wheat, vegetables and alfalfa cultivation. Also, they are good for plantation establishing. Total area of this class is 58 600 ha; i.e. **0.4%**

Soils: Chernozems, Fluvic cambisols of the best quality, Cambisols originating from loams or Cambisols from clay bedrock.

Class II. Soils better arable

Soils are almost the same in origin and of similar properties like previous category. Although for cultivation of these soils some agronomical operations are necessary. These soils are reported in area of 454 200 ha; i.e. **3.1%.**

Class IIIa. Soils well arable

These soils placed on bad physical and chemical properties or they are located in bad physiographical conditions. Differences between this class and previous one is in soil moisture (groundwater level may have a big swings). That is a reason of shortlist of useable plants for planting. These soils are starting to be harder for cultivation as well. Also they exhibit sings of degradation and in the case of Luvisols the A horizon in fresh conditions is often in grey or light grey colour. Under good agricultural techniques they provide huge returns of rye, oat, potatoes lesser wheat, beetroot and colza. Total area included in this class is around 1,465 million hectares; i.e. **10.1%** of polish area.

Soils: Cambisols and Luvisols created from clayey sands with high level of calcification, Umbrisols, Sandy Fluvisols, some Rendzinas and Histosols under influence of melioration.

Class IIIb. Soils moderately arable

Substantially, this class is closely by conditions to previous soil class IIIa but with worse physical and chemical conditions or physiographical one. Also swings in groundwater level appear in bigger influence and agronomical returns depended on climatical conditions, some of them are described either like dry or wet. Soil may be under erosion as well. Also cultivation is worse in previous class. These conditions are good for planting wheat, beetroot and clover. Area which is occupied by this soil class is spreads on 2 million hectares; i.e. **13.9%** of polish land.

Soils: Cambisols, Retisols and Luvisols, Phaeozems, Rendzinas and Histosols

Class IVa. Arable Soils of moderate quality (better)

This class is characterised by low choice of plants than in last class as well as agroeconomical returns are lower but when good agromonical techniques are used. They are located in bad natural conditions, in somewhere in terrain depression, with high precipitation and under water erosion. They have low biological activity, low temperature and they are harder to cultivate. Under good climate conditions and good cultivation they are able to give moderate returns of wheat, beetroot, and clover. Class is dominating on **22.5%** of area; i.e. 3,296 million hectares.

Soils: Cambisol, Luvisols and Podzols created from different grain-size sands and pebbles. Soils developed on deeper rock bed may be substituted by Cambisols, Luvisols and Stagnosols created from clayic sands which occurred after sandstone weathering, created form clays and dust of low quality.

IVb. Arable soils of moderate quality (worse)

Soils contained in this group have the same conditions as class IVa but they are more degrade or moister than previous one. Soil using is more diverse and it depended on atmospheric conditions. These soils are often under influence of groundwater, worse for cultivation or they are located in bad physiographical conditions (in wet conditions, on slopes under erosion, etc.). They are used for pasture or used for plantation of oat, clover, cabbage or other plants used for feeding animals. Rarely these soils are used for plantation of fruit trees. Its occurrence in Poland is 2,462 million hectares; i.e. **16.8%**.

Soils: Almost the same types like in IVa. group but under worse conditions as higher groundwater level or under erosion. Also they are situated on places with higher possibility of erosion.

V. Weakly arable soils

These soils are described like soils which are poorly fertile and almost dry. They are very light, dry and they can be used for planting wheats; if high amount of water occurs the potatoes can be planted there. Planting plants and trees depend on water conditions and level culture. It means some fruit tree species can be planted on these soils.

Under influence of groundwater, these soils may be used for planting rutabaga, cabbage, grass or some species used for pasture. In Poland this group may be found on 3,062 million hectares; i.e. **20.9%** of polish area.

Soils: Cambisols, Arenosols, Gleysols and Luvisols formed from sandy and clayic gravels, sands with low percentage of clay on consolidate calcite rocks.

VI. The most poorly arable soils

These soils are weak, flawed and unreliable, crops grown on these plants are very low and uncertain. These include soil too dry and loose, which goes lupins, while rye only in favorable years gives average yields. Very shallow soils or strongly rocky shallow, consequently difficult to grow, the soil too wet for ever for high ground water level, often with storfiałą or murszastą decay in which to carry out the drainage is very difficult. In fact, these soils are suitable for afforestation more than the cultivation of agriculture. At the very shallow humus-rich soils of this class, you can only cultivate rye and white clover.

This type of soil occurs on 1,846 million hectares; i.e. **12.6%** of polish arable land.

Soils: Class VI soils include rust, Podsols, Rankers, shallow initialised Rendzinas and heavy alluvial wetlands.

4. CZECH REPUBLIC

4.1. Pleistocene and glacial period in Czech Republic

Czech territory was "only partiallly affected" by glaciation in Pleistocene. Králík (1989) stated that our land was covered by glacier only twice – in penultimate Riss glaciation and in Mindel glaciation. First glaciation as Piotrowski (1998) defined, was especially presented by ice of the Polish Odra glaciation. ´´Also the eastern glaciated part of northern Moravia and Czech Silesia was glaciated by ice sheets that combined both the Vistula and Odra lobes´´ Marks (2005). Their occurrence can be found in Šluknovský and Frýdlandský spit and in Czech part of Žitavská basin of Northern Bohemia. Also evidences of glacier occurrence are recorded in Ostrava region and Podbeskydska Upland, around Opava, in Osoblaha lowland, also in Žulovské Mountains and in Zlaté Mountains as well (Macoun et al. 1965). Table bellow represent a time when our land was covered by glacier.

Table no.3, **Comparison of Northern Europe continental glaciation, Moravskoslezke glaciation and Alpinic glaciation** (According to Pavurová, 2011)

Plestocene	**Glaciation/ interglaciation**	**Stratigraphycal system**			
		North European		**Moravia Silesian glacial area**	**The Alps**
Middle Pleistocene	Glaciation	Saale	Saale 1	Oldřichovský	Riss
			Saale 2	Palhanecký	
	Interglaciation	Holstein		Stonavský	Mindel/Riss
	Glaciation	Elster (Halštrovké glaciation)	Elster 3	Kravařský	Mindel
			Elster 2		
			Elster 1	Opavský	

4.1.1. Geomorphology, geology and location

Osoblaha is situated in Czech part of Silesia, in north-eastern part of Opava region. Northern borders of the area are created by border with Poland and by Nízký Jeseník on South.

According to geomorphological division area is situated to Hercynian system, Epihercynian lowlands subsystem and Middle European lowlands province; Kolář, Boháč (1996). Following division in the system is Middle Polonian lowlands subprovince which continues to Silesian lowlands region and Opavská upland; Demek (1987).

Middle Polonian lowlands type according to Bína a Demek (2012), takes area of only 395 km² in Czech republic (around 0,5% of total cover). It's the least coverage of all three systems in our country

In table no.4, there is a summary of this geomorphological condition (Based on Demek, 1987).

Table no.4, **Summary of geomorphological divisions**

System	**Subsystem**	**Province**	**Subprovince**	**Region**	**Unit**	**Subunit**
Hercynian	Epihercynian	Mid.Europe lowlands	Mid. Polonian lowlands	Silesian lowlands	Opavska lowlands	Osoblaha lowlands
						Poopavska lowlands
						Hlučínská lowlands

Surface of Opavský bioregion according to Culek et al., (1996), consists of quaternary sediments deposited from glacifluvial gravel and sand, mixed material from moraines and Eolithic clay with various stratifications. Subsoil is formed by calcareous marine material (clay, sand and mixed material) and it is denudated surface around Opava. Marlite and upper cretaceous sandstones are found around Osoblaha town.

It was stated that Osoblaha lowlands was covered by ice. Accumulation of certain sediments from this era was documented by Chlupáč (2002), who classified these quarternary sediments on basis of genetical aspects into three main groups as; Glacier (glacial), terrestrial sediments of non glacied areas and out of Czech Republic there are marine sediments. But according to Bína and Demek (2012), sediments around Osoblaha are formed by glacifluvial sediments and alluvial terraces covered by loess and loess loams. These formations of soil on fluvioglacial parent material occured in general area of these cities but soil samples taken and used for purpose of this thesis are collected from Chuchelná. It is a small city in Poopavská Lowlands. Sediments are described in following chapter

4.1.2. Glacifluvial sediments

These sediments are the most significant structures in complexes of continental glaciation. Lithologically they are formed of sands, sandy gravel or gravel and they are mainly (1) obliquely or crossly undulated (2) somewhere rhythmic sedimentation is conserved or (3) goes to glacilacustrian sediments settled in shallow basins. Also erratic boulders are found very often with diameter up to 1 meter. This material is mainly consisted of sandy or sandy gravel fraction. Glacifluvial sediments also contain clay which is found in lakes or shallow basin. Sediments represent chiefly Riss glaciation, older sediments are conserved in depresions and represent material originated before Minden glaciation; Sedláček (2008).

4.1.3. Coluvial sediments

Coluvial sedimests defined by Šimíček (2008) are scarcely present in Osoblaha which is caused by lower rolling ground. It´s created by solifluction sediments which incorporates rocky loam and rock deluvium. On right bank of Osoblaha river, the Holocene coluvial sandy loams sediments are present as well.

4.1.4. Glacilacustrinian sediments

The most common types of these sediments are basal clay. Also there is occurrence of tills from fluctuate front moraines. Thickness of these tills is estimated to 2 – 3 metres but in areas with rugged topography the thickness can be up to 10 metres. There are two different colour types. Dark gray to black includes Mindel glacial and light gray and brown are assigned to Riss one. Basal tills were found out in Libverdy spa, on west from Frýdland to Bukovské hills and on northwest hill called Vyhlídka. Other tills were found in Raspenava and Frydlant-settlement. In addition to basal tills. Till are known as oscillating end moraines, as is the sandpit in Řasnice (younger Riss glaciation); Sedláček (2006).

4.2. Soil classification and land use in Czech Republic

Soil as Hauptman et al. (2009) defined ,,is a top part of Earth surface which is formed by compounds of mineral elements, dead organic matter and living organisms. It´s vertically divided, connected with its parent rock and it´s created from weathered or unconsolidated mineral and organic sediments". Compared with polish classification of soil under arable land and forest stand the Czech classification use mainly Czech taxonomical classification system, WRB and special classification system from soils under arable land and our has not so clear definitions soil according to their structure, amount of nutrients, cultivations etc. In few paragraphs these systems will be described

4.2.1. Czech Taxonomical Classification system (TKSP)

This system was updated in 2001. System as Vopravil (2010) stated is based on soil grouping due to their genesis, diagnostic characteristics and horizon coloration and others mainly analytical characteristics of soil. It´s consisted of these taxonomical categories:

- Reference class
- Soil type
- Soil subtype
- Soil variety
- Local soil forms

This system is according to Sládková (2010)

Reference classes (groups) **of soils** (15 total): the basic units of the world classification systems. Names are ending with suffix –sol.

Soil types (28): basic units of the Czech system, characterised by the presence of certain diagnostic horizon or horizons and/or specific diagnostic features. Soil name is derived from specific noun, sometimes ending with suffix-zem or other, -sol.

Subtypes: distinctive modifications of the soil type, expressing the central conception of the type, transitions to other types, remarkable lithological or genetic features (arenic, pelic, etc.), specific traits like debasification, salinisation, sodisation, distinctive hydromorphic and anthropic influences. The name: an adjective placed before the name of the soil type.

Varieties: less distinctive modifications of the soil type, features of top horizons up to 0.25 m deep. The name: specification of the adjective describing the subtype.

Local soil forms: distinguished according to the details of particle size distribution, skelet content, slope (exposition, inclination, the form of slope).

4.2.2. World Reference Base (WRB) according to Jones et al., (2005)

The WRB system is a two-level system of soil classification with 30 Soil reference groups and a series of uniquely defined qualifiers for specific soil characteristics.

For describing and defining soils the WRB exploits the following nomenclature:

- Soil characteristics comprise single observable or measured parameters;
- Soil properties are a combination of characteristics indicating soil-forming processes;
- Soil horizons represent three-dimensional bodies containing one or more soil properties

Soil horizons and properties are used to describe and define soil classes if they are considered as being ”diagnostic”. This means reaching a certain degree of expression, as determined visually, by prominence, measurability, importance and relevance for soil formation, soil use and quantitative criteria. To be diagnostic, soil horizons also require a minimum thickness.

These two systems are compared bellow. Table shows what is a difference descriptions of soils in TKSP system and WRB system (annex no. 1, taken from www.klasifikace.pedologie.cz)

4.2.3. Estimated pedological ecological Unit

Production potential of agriculture land fund in the Czech Republic and Slovakia is evaluated by “estimated pedologic-ecological units” (BPEJ); Středová, H., Chuchma, F., (2014). In Czech the acronym used is BPEJ. Vopratil (2011) defines its significance in five-digit code. The first number expresses the climatic region. The second and third number classifies soil included in main soil unit classification system. Fourth number presents slope and expositions to cardinal directions and their combinations and fifth one describe soil depth and soil stoniness and its combination. Overview of code values is presented in table no.

Table no.5, **Description of BPEJ code**

Description of EPEU code		
EPEU code schematization: x.xx.xx	**Code description**	**Numerical code range**
x	Climatical region	0 - 9
xx	Main soil unit	01 - 78
x	Exposition and slope	0 - 9
x	Soil depth and stoniness	0 - 9

4.3.1. Soil samples from Czech Republic

Two soil profiles were assessed near Chuchelná at Czech-polish borders. Location of profiles was selected according to land use. Figure no. 2, depicts the location of assessed profiles. First profile is located on coordinates N 49° 59’ 13” and E 18° 6’ 2” on arable land along road. Second one is located in pine forest stand approximately 5 metres from road no 46824, going from Bolatice to Chuchelná on coordinates N 49° 58’ 85” E 18° 05’84“. Both of them are characterised by LPIS application and classification by BPEJ.

Figure no. 2 **Localities in Czech Republic**, Source: www.mapy.cz

4.3.2. Soil samples from Poland

Selected soils in Poland also occur under different conditions. These specifics are represented by soil under forest stand, soil of arable land and non-tilled.

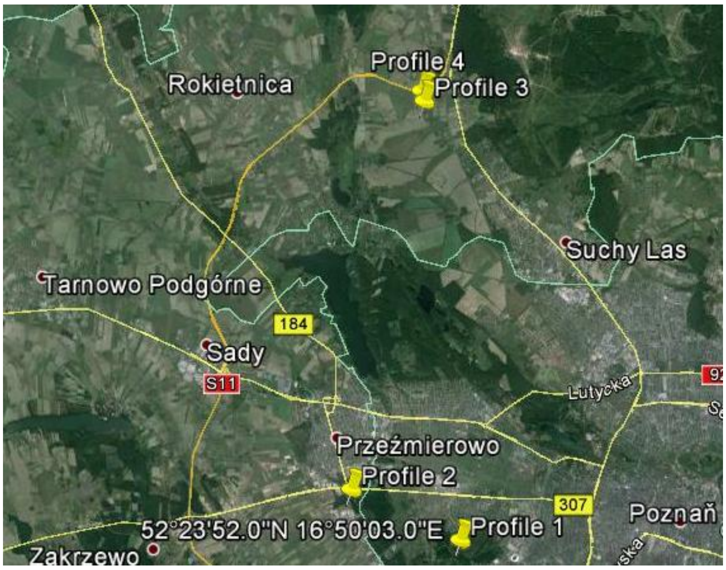


Figure no. 3, **Localities in Poland**, Source www.google.maps.com

Location of these soils is at outskirts of Poznań (Figure no.3) where these soils were collected and used for analyses. Coordinates of Profile number 1 are N 52° 23’ 52” and E 16° 50’ 3”. Where soil is influenced by pine forest stand. Approximately 2 kilometres from first profile, the second profile is located with coordinates 52°24'37.0"N 16°47'24.0"E. Soil in this place is covered by pioneer trees and it is not without use. On northern part of Poznań there is a city called Zlotkowo where last two profiles are located. Both of them are around 500 meters from each other on arable land (stubble after triticale) but under different conditions. Profile no.3 is located on dry soil while Profile no.4 is under influence of water. Profile number 3 is characterised as Haptic Arenosol with low water-holding capacity. This soil is found on 52°30'28.1"N 16°49'10.4"E. Last soil profile (profile number 4) is near previous one on coordinates 52°30'28.1"N and 16°49'10.4"E. In Poland there is no BPEJ classification comparable to Czech Republic, all what is needed for its classification is written in annex no.1. Datas of Poznań climate conditions from 1995 – 2015 for determination of climate region are shown in annex no.9, Poznań climate conditions (1995 – 2015) (taken from http://en.tutiempo.net/climate/ws-123300.html).

Table no.6**, Comparison Czech and polish soils according BPEJ**

	Estimated pedological ecological unit				
	Profile	Climate region (**X.**xx.x.x)	Main soil unit (x.**XX.**x.x)	Exposition and slope (x.xx.**X.**x)	Soil depth and stoniness (x.xx.x.**X)**
Poland	**1**	**5**	**21**	**0**	**0**
	2	**5**	**21**	**0**	**0**
	3	**5**	**21**	**0**	**0**
	4	**5**	**21**	**0**	**0**
Czech Rep.	**5**	**5**	**14**	**0**	**0**
	6	**5**	**21**	**0**	**0**

Table no.6, shows comparison of Czech and Polish studyed soils according to BPEJ classification system. Climate region (**5**.xx.x.x) has defined by the same conditions in Poland and Czech Republic. Region is characterized as MT2 (mildly warm) with slightly warm, slightly dry conditions.

Main soil unit (x.**14**.x.x., x.**21**.x.x) represent soil located on study area. Number 14 describes Modal Luvisol, Luvic Brown soil including lightly gleyic on gleyic loess loams (dust loam) or slope (polygenetical) loams with a strong eolithic admixture, medium heavy, heavy base with favourable rainfall conditions. Number **21** is related to soils of arenical subtype of regosols, pararendzinas, cambisols or even fluvisols on light, not arid, strongly desilicated substrates.

Fouth place (x.xx.**0**.x) describes an exposition and stoniness. All studied profiles are classified as planes with slope angle from 0 to 3 degrees, without distinction of expositions. Fifth position (x.xx.x.**0**) describes soil depth and stoniness. **0** means soils without stoniness and of deep soil profile**.**

4.4. Land use in Czech Republic

4.4.1. Forestry

The Czech Republic is a country with a large woodland area. Woodland currently covers 2 651 209 hectares, which is 33.7 % of the total area of the state. The area of forest land has been systematically increased since the middle of 20th century**.** The Czech Republic therefore takes 12th position in the European table of forest percentage. Woodland areas are gradually increasing (by around 2000 hectares a year) in consequence of the long-term aforestation of agricultural land (MZe ČR, 2016).

Tree species ratio and stand composition

According to Krejzar (2014), the total area of dominant coniferous species, i.e. spruce, pine and larch, further declined, while the share of fir has been continuously showing a slight growth to current 1.1%. In contrast, the share of broadleaves, particularly beech, has increased. When assessing the species diversity of national forests, the overall proportion of individual tree species is the major indicator, along with the distribution of forest stand admixtures within individual units of spatial arrangement of forests. The proportion between individual tree species within a unit has been continuously increasing in favour of mixed forest stands and forest stands with prevailing broadleaves, which was also the case in the year 2014. This increasing trend is a result of foresters' unyielding effort to acquire optimal species composition of forests, a practice that gets a long-term support under a goal-oriented national incentive policy.

Forest ownership

Equally to the preceding years, the year 2014 did not bring any substantial changes in the ownership structure of forest land.

Most forest land is owned by the state and is predominantly managed by Lesy České Republiky (Forests of Czech Republic, State Enterprise) (50,16%). Private entities and municipalities represent other major forest owners, while the remaining forms of ownership are rather marginal and statistically less significant. More substantial modifications in the ownership structure are to come in the following years as a result of restitution of forest property to Churches. Krejzar (2014).

4.4.2. Agriculture

Agricultural entrepreneurs cultivate approximately 4.264 million hectares of agricultural land in the Czech Republic, which represents (54 %) of the total country area. Area of agricultural land in Czech Republic is 0.42 hectares *per capita,* 0.30 hectares of this being arable land (which corresponds to European average). More than one-third of the land fund of the Czech Republic is covered by forest. There has been a decline in agricultural land area reported at 15 thousand hectares and an increase by 16 thousand hectares of woodland since 1995. (MZe ČR, 2016).

Most agricultural land is now owned by private subjects and legal entities. Some 599.7 thousand hectares of land were owned by the state by 31 December 2004 and rented out by the Land Fund of the Czech Republic. Czech and Moravian agriculture can be characterised by the serious fragmentation of land ownership and vast percentage of land under lease (90 %) to wide scale of subjects. The size structure of enterprises is highly different compared to structure of industry in 25 member states of the European Union. Enterprises with ownership of more than 50 hectares of agricultural land occupy 92.2 % of the total area of the agricultural land farmed. (MZe ČR, 2016).

5. Material and Methods

There is a detailed methodology used in thesis. Methods which are focused on physical cylinders and soil activity are very common. However, description activity of soil phospatase, urease and Cmic is related to Methodologies of Mendel University. If anybody abroad would repeat analyses, there is a method, how to do it.

5.1Physical Properties of Soil

5.1.1. Cylindrical Core Method

Cylindrical Core Method is widely used to determine bulk density and other physical properties of soil, but can be also applied to calculating water and air regime of soil. The main device of this analysis is so called Kopecky's physical cylinder, usually made from stainless steel of inner volume of 100 ccm and maximum height of 5 cm. Cylinders, also known as core cutters, are fully driven (usually hammered) into straightened soil profile with the aid of steel rammers. Soil around the cylinder is excavated and the cylinder is undercut with a knife. Core cutter is carefully lifted and both surfaces of the sample are flat trimmed. The outside surface of the cutter is cleaned. Lids are placed on both cylinder sides and are tightened with rubber bands if necessary. Cylinders are properly labelled. Samples should be taken directly to the lab and refrigerated if not being processed straight away.

1. Take the lids off and weigh the cylinder placed onto small round filter paper to record initial field-moist humidity. Filter paper, the sample is initially placed upon, is included in all further measuring.
2. Cylinders are allowed soak in water till their suspension is saturated (samples are shiny on the top). This procedure takes place for 24 hours and is carried out on wood planks wrapped in filter paper and half submerged into water. Samples should be covered to avoid excessive water of evaporation.
3. When saturated, cylinders are weighed again.
4. Soil samples are set aside onto four times folded sheets of filter paper (or simply four sheets of filter paper) and left to drain for 30 minutes. At this time water content is drained from the greatest non-capillary pores. Samples are put back onto filter papers after weighing.
5. This process is repeated after another two hours. Values at this time describe the state of maximum capillary water capacity and minimum air capacity. Final

‘wet’ weighing takes place 24 hours after the first saturated measurement. This is important for distinguishing between capillary and semi-capillary porosity, as well as for obtaining approximate retention water capacity values.

6. Soil samples are oven dried to constant weight at 105 °C. Weighed when cooled down to room temperature.
7. Soil samples are carefully pushed out of the cylinders into a standard enamel laboratory dish and are left to stand together with the core cutters for 7 days to reabsorb atmospheric humidity.
8. Both soil samples and cylinders together with filter papers are weighed, only this time separately. Precautions are taken to include the entire soil sample: each sample is handled with utmost care to avoid losses and spillages; residual soil has to be scraped of the cylinder.

5.1.2. Determination of Specific Gravity of Soils

Applied soil analyses of specific gravity is usually described as the ratio of the weight of any volume of soil material to the weight of any volume of water. Calibrated 100 ml pycnometers are utilized in the process of specific gravity determination, calculation is performed according to equation no.1.

1. Soil samples are oven dried to constant weight at 105 °C and sieved through 2 mm mesh.
2. Empty pycnometers are weighed (glass stoppers are always included in the weighing)
3. Each pycnometer is filled to about one fifth of its height with soil samples of about 10 g. Weight of samples is recorded.
4. Demineralized water is added to the pycnometer to cover the sample and reach to about one quarter of the height of the pycnometer.
5. Pycnometers are placed on a hot plate and their contents are brought to rolling boil. Boiling the contents for about 5 minutes effectively expels all air content out of the sample. The sample solution must not boil out of the vessel, precautions are taken: wash bottles are used to slow down the boil or flush the sides of the vessel.
6. Pycnometers are cooled and filled to the brim with demineralized water. Stoppers are pushed in with a swift move making sure that there is no residual air in the container.

7. Pycnometers with soil samples and water are weighed and this weight is subsequently compared to the weight of pycnometer filled with water only according to the equation bellow. Results of specific gravity are given in g . cm^{-3}

Equation 1. Calculation of specific gravity (ρ_s), where m_1 stands for the weight of the soil sample (g), m_2 is the weight of pycnometer filled with demineralized water (g) and m_3 represents the weight of pycnometer with boiled soil water suspension.

$$\rho_s = \frac{m_1}{m_1 + m_2} - m_3$$

5.1.3 pH Determination

pH of soil was measured in agreement with Zbíral's methodology published in Analýza půd I (2005) and that is also in accordance with a current international standard ISO 10390:2005 and its Czech counterpart national standard ČSN ISO 10390 (836221). Applied method of routine determination of pH is using a glass electrode in a 1:5 (volume fraction) suspension of soil in water (pH in H2O) and of potassium chloride solution (pH in 1 M KCl). This procedure should be applicable to all types of dry soil prepared according to ISO 11464:2006 (Soil samples were dried in an oven at temperature not exceeding 40 °C, subsequently crushed and sieved resulting in fraction smaller than 2 mm).

1. Preparation of soil suspension acquires measuring 5 ml of prepared soil sample (or an equivalent of soil in grams) into 125 ml screw-top plastic flask and adding 25 ml of solution medium (demineralized H_20 or 1 M KCl).
2. Extraction is performed on mechanical shaker for 60 ± 10 minutes. Suspension is left to stand for another 60 minutes after shaking and only after than the measurement takes place. The total time of contact of the soil with the solution before measuring the pH must not exceed 4 hours.

5.1.4 Dry Matter Determination

The principle of dry matter (DM) determination in soil is based on heating soil samples to temperatures at which water is evaporated. The results are calculated from the weight difference of samples before and after drying and are expressed in grams of dry matter or in percent (dry matter content per fresh soil weight), (Equation 2).

1. Aluminum dishes with imprinted serial numbers were used for the process of drying. The dishes were weighed first and their weight values were recorded against their serial numbers.
2. 10 g of fresh soil was than weighed on laboratory scales with the accuracy of ± 0.01 g and placed in each dish.
3. Prepared samples were dried in an electric oven at constant temperature of 105 ° C for at least 2 hours.
4. The dishes with samples were left to cool down at room temperature and were subsequently weighed.
5. Dry matter content was calculated according to the below equation.

Equation 2 Dry matter calculation formula (results are in %), where m_∞ stands for the weight of dish with sample after drying, m_0 stands for the weight of an empty dish and m_1 stands for the weight of a dish with fresh soil sample.

$$DM = \frac{m_\infty - m_0}{m_1 - m_0} * 100$$

5.2. Activity of soil enzymes

5.2.1. Assays on soil microbial carbon (C_{mic})

Used process of soil microbial biomass evaluation comprises of two separate methods by Central Institute for Supervising and Testing in Agriculture (Zbíral et al. 2011) where the first serves as a lead-up for the other. Therefore, both procedures, the Chloroform-Fumigation K_2SO_4 extraction method (normative 31010.1) and the Determination of Oxidizable Organic Carbon in (K_2SO_4) Solution (normative 31020.1), were respectively carried out; hence the division in described laboratory procedure. However, either of applied methods drives at the same result, which is content of extractable carbon of microbial biomass expressed in micrograms per gram of dry matter in soil ($\mu g . g^{-1}$).

Both procedures compare the amount of organic carbon in a chloroform-fumigated soil sample to that in a non-fumigated so sample to determine soil microbial biomass. The Total Organic Carbon content (TOC) will be higher in the chloroform-fumigated sample because the sample contains the cell contents of lysed microbial cells. Hence the difference in extracted TOC between fumigated and non-fumigated examples will provide measure of microbial biomass. Note that you can only assume that this TOC in the soil is of microbial origin. Samples have to be picked free of roots, litter, earthworms, etc., since the microfaunal contribution to TOC is usually less than 5 %.

Final results are calculated only from the second part of the procedure.

5.2.2. The Chloroform-Fumigation with K_2SO_4 extraction method (Part 1)

Humification is carried out for a period of 24 hours in vacuum desiccators with the addition of chloroform. It is important to refrigerate soil samples at 4 °C until the fumigation and K_2SO_4 extractions are performed.

1. It is preferable to prepare required amount of 0,5 M K_2SO_4 first (Use magnetic stirrer while warming the solution).
2. Field-moist soil samples (pre-sieved through 2 mm mesh), free of visible roots and organic debris, are mixed thoroughly to become homogenous.
3. Plastic 50 ml flasks are to be labeled as to distinguish between non-fumigated (NF) and fumigated (F) samples. All samples are run in triplicates.
4. Weigh 5 g of soil into each flask (water content should be in the 20 to 30 % range for best fumigation results).
5. Chloroform fumigation: vacuum desiccators are cleaned and covered at the bottom with filter paper. Filter paper is moistened with demineralized water and F flasks are placed inside of the desiccator.
6. 100 ml beaker is placed inside the desiccator. Glass beads and alcohol free chloroform are added to the beaker. About 2 g of NaOH drupelets in a smaller beaker are also placed inside the vessel to absorb atmospheric CO_2 during fumigation. Vaseline is applied to all contact areas between the main vessel, the lid and the valve and the desiccator is closed.
7. Vacuum pump is turned on, as is the opening valve. Vacuum created in the desiccator causes the chloroform to boil and evaporate, and of course, to saturate the desiccator's atmosphere. The chloroform is allowed to boil vigorously for five minutes yet it should not spill out of the beaker. Turning off the valve seals the desiccator. The fumigation process should take place for 24 hours.

8. Beaker is removed after upon opening the fumigation vessel and chloroform is allowed to evaporate. It is important that all residual chloroform is removed from the soil samples before proceeding with K_2SO_4 extractions. The flasks may be placed in fume hood with open windows in the room to increase the velocity of the wind flowing over the flasks. This procedure should be allowed to take place for at least 30 minutes.
9. 20 ml of 0,5 M K_2SO_4 is added to each flask. Flasks are closed tightly and rotary shook for 30 minutes at about 200 rpm.

K_2SO_4 extracted soil samples are oxidized in strong acid medium with the addition of potassium dichromate and spectrophotometrically analyzed for TOC content. Analysis results need to be adjusted to TOC/g dry soil value.

10. Soil suspension is poured into labeled plastic cuvettes and the samples are readied for centrifugal sedimentation at 4000 rpm for 5 minutes.
11. 1 ml of clear, sedimented F sample is pipetted into labeled 25 ml flasks together with 1 ml of K_2SO_4 (NF samples are prepared only with 2 ml of sample). 3 ml of oxidation reagent consisting of 10 ml of 0,025 M potassium dichromate ($c(K_2Cr_2O_7)$ = 25 mmol/l), 25 ml demineralized H_2O and 73 ml 95% H_2SO_4 is also added to all flasks.
12. Blanks are prepared similarly but only 2 ml of K_2SO_4 solution and 3 ml of oxidation reagent is added to the 25 ml flasks. For the best result triplicate blanks as well.
13. All balloon flasks are put onto preheated hotplate set to 150 °C and the oxidation is allowed to take place for 30 minutes.
14. Samples are set aside to cool down to room temperature and than spectrophotometrically measured (λ = 340 nm) in constricted 0,5 cm cuvettes.

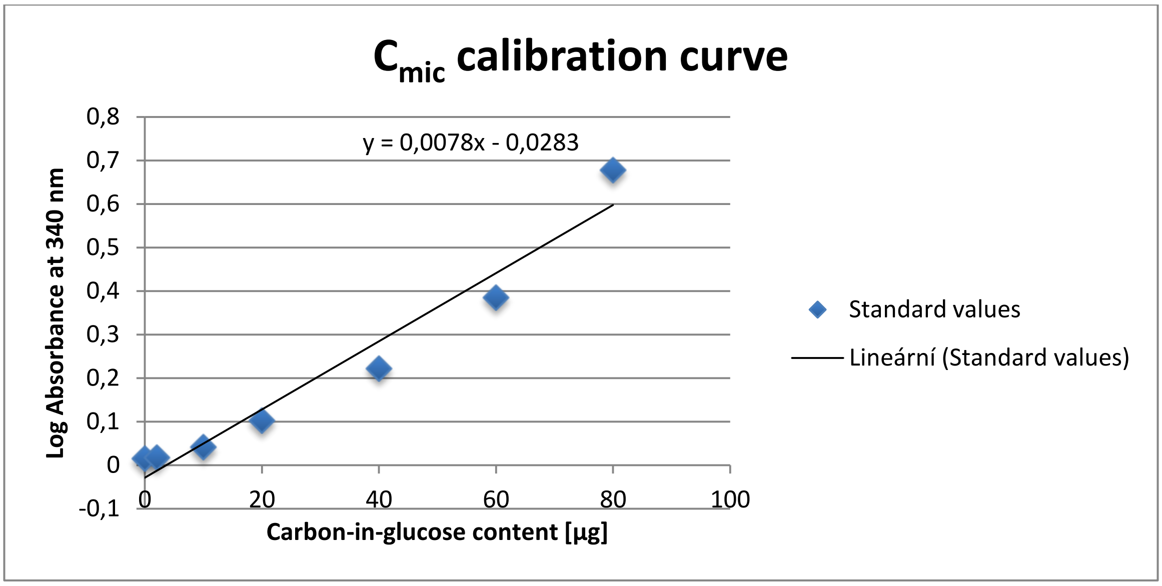


Figure 7 Log Inverted graph used for establishing carbon content of microbial biomass (C_{mic}) with projected linear calibration curve of spectrophotometrically measured values of carbon-in-glucose content in K_2SO_4 standard solutions.

5.2.3. Urease Activity Determination

Urease activity in soil was examined with the aid of Kandeler's and Gerber's method of colorimetric determination of ammonium published in 1988.

The method comprises of incubation of soil with an aqueous and buffered urea solution at 2 hours at 37 °C in order to release the enzyme from protected locations in soil suspension, extraction of ammonium with KC1/HCI and spectrophotometric determination of released ammonia. Urease activity expressed as µg of hydrolysed N /g dry soil/ 2 h at 37 °C.

1. Field-moist soil is gently triturated before being sieved on a 2 mm screen to separate larger fractions.
2. 2,5 g of soil is placed into 120 ml plastic incubation flasks and wetted with 1.25 ml aqueous urea of M 0,72 solution ($c(CH_4N_2O)$ = 0,72 mol/l). All samples are run in triplicates.
3. The flasks are stoppered with lids and placed into an incubator set to 37 °C, taken out after 2 hours.
4. 15 ml KC1/HC1 (1 M KCl to 0,05 M HCl) is added and the mixtures shaken on a mechanical shaker for 30 min.

5. Control samples were prepared as above with the exception that urea was substituted with demineralized water and added only after incubation immediately before the HCl/KCl adition.
6. The resulting suspension is poured to centrifuge cuvettes and spun at 4000 rpm for 5 minutes.
7. 1 ml of clear sample solution is transferred to 50 ml flasks and 9 ml of demineralized water is added (1 ml is effectively diluted to 10 ml). Successively add 5 ml of Na-salicylate (prepared from: 100ml 0.12% Na-nitroprusside, 100ml 17% Na-salicylate and 100 ml demineralized H_2O) and 2ml 0,1% Na-dichlorisocyanurate.
8. Let the solution stand at room temperature for at least 30 min.
9. Absorbancy of all samples was measured at 690 nm (ƛ = 690 nm).

Pre-constructed calibration curve was, again, used in the process of final results computation. It was constructed from spectrophotometric readings obtained from standard solutions. 3.8207g NH_4C1 was dissolved in 1000ml water to prepare the standards. The NH_4~N content of the solution was calculated by reference to a calibration graph (Figure 8) plotted from the results obtained by pipetting 0, 0,15, 0,3, 0,6, 0,9 and 1,2 m1 of 0,382% NH_4Cl into 100 ml flasks, which were additionally filled to the 100 ml mark with the HCl/KCl solution.

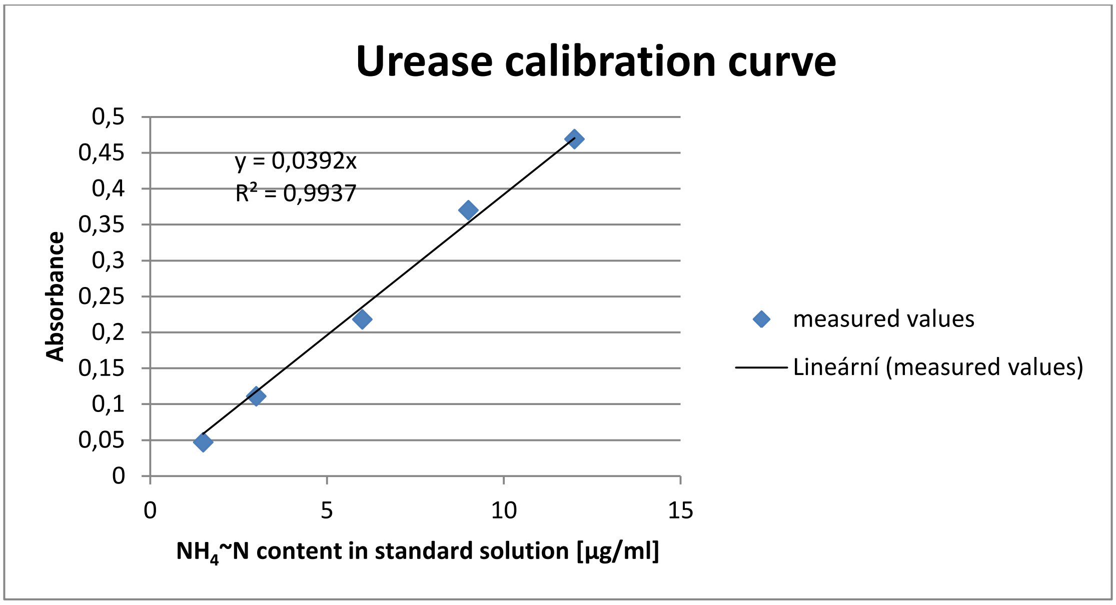


Figure 8 Urease calibration curve of spectrophotometrically measured values of NH_4~N in HCl/KCl standard solutions

It is necessary to construct a calibration curve for used microbial biomass computation. This calibration curve (Figure 8) was prepared by spectrophotometrically measuring standard samples with various carbon-in-glucose concentrations (0; 2; 10; 20; 40; 60; 80 µg C/ml) in K_2SO_4 solution.

Equation 3 Extractable content of oxidizable carbon calculated to dry matter content (DM) in soil (µg . g^{-1}), where w is the initial soil sample water content (%), m stands for DM corresponding with the content of fresh soil (g), V is the volume of extraction reagent and C_{sol} stands for the concentration of oxidizable carbon content in the extract derived from calibration curve calculations (µg . ml^{-1}).

$$C_{mic} = C_{sol} * \frac{V + \left(\frac{w * m}{100}\right)}{m}$$

5.2.4. Acid Phosphomonoestherase Activity Evaluation

Applied laboratory analysis is based on Tabatabai's and Bremner's procedure (1969) that was later modified by Rejšek (1991) and applies p-nitrophenol phosphate (p-NPP) added to working buffer solution. Enzymatic activity releases p-nitrophenol (p-NP), which is extracted and colored by potassium hydroxide (KOH). The phosphomonoestherase activity is measured spectrophotometrically. Results are determined according to absorbance of analyzed samples at wavelength of 410 nm and the phosphomonoestherase activity is expressed in µg p-NP/g DM/hour, where DM stands for dry matter.

1. 1 g of field-moist soil is weighed into 100 ml Erlenmeyer flask and working buffer solution (of sodium perborate and succinic acid) containing 750 µM/l p-NPP is added. Shake the flasks briefly and incubate for one hour at 37 °C.
2. Filter the solution into plastic cuvettes, add 8 ml of 1 M KOH. Yellow coloration of ions should occur due to strong alkalization. (Alkalized filtrates can be diluted with working buffer solution in 1:1 (1:2) ratio if necessary.
3. Control measuring has to be performed in parallel with each analysis that is carried out. The occurrence of yellow colouring, which did not derive from p-NP release by acid phosphomonoesterase p-NPP breakdown, has to be considered. Therefore, control samples, prepared similarly, have to contain pure working buffer solution without p-NPP. 12 ml of working buffer solution with p-NPP is added to controls after incubation (just before filtration). Twice the amount of KOH has to be subsequently added to retain the dilution ratio.
4. Absorbance of standard solutions with known p-NP concentration is used for calibration curve construction.
5. Absorbance of analysed samples and standard solutions is measured at 410 nm.

5.3. Catalase Activity Evaluation

Determining the activity of catalase in soil is practically the same as quantifying the capacity of soil to decompose hydrogen peroxide (H_2O_2) to water and molecular oxygen. The reason behind measuring the production of O_2 (generated due to the presence of H_2O_2 in the original suspension) and, therefore, the evaluation of the biological activity of soils lies in the presence of microflora capable of producing an enzyme (catalase) catalyzing this reaction. Used procedure was drawn up by Káš in 1954 and gas volumetrically measures the amount of O_2 evolved within 15 minutes period. Catalase activity is expressed in: ml O_2 $5g^{-1}$ 15 min^{-1} and is considered to be very low if lower than 5, low if between 5 –15, medium if 15 –30, high if 30 – 60 and very high if more than 60.

Device called Vápnoměr dle Janka is essential for this procedure. Is is a system of two graduated eudiometric measuring tubes 0 –100 ml connected with rubber tubing at their lower ends. The first of the tubes is connected with Erlenmeyer flask (containing an automatic pipette) through the rubber tubing and a three-way stopcock. The system also contains a reservoir bottle connected to both tubes at the lowest part.

1. Weigh 10 g of mineral (or 5 g of organic) field-moist soil into 250 ml Erlenmeyer flask and add 50 ml of demineralized water.
2. Introduce water from the reservoir into the manometer system of two connected eudiometric tubes until it reaches top calibration marks. Lock the system with tightening screw and introduce 20 ml of 3% H_2O_2 into the automatic pipette.
3. Connect the pipette to the Erlenmeyer flask with the rubber stopper. System has to be airtight. Three-way valve can be opened. Pour the hydrogen peroxide solution from the automatic pipettes into the flask.
4. Briefly stir the suspension and start measuring time. Stir the contents of the flask every five minutes.
5. Note the level of water in the first eudiometric tube after fifteen minutes (in case of intensive oxygen production pressure in the system can be lowered by releasing excess water from the system into the reservoir bottle).

Since each grade on the scale (‘0,1’) represents 5 ml of newly produced O_2 it is relevant to divide the resulting number on the grade by two providing the initial soil sample was 10 g. Final step is to recalculate the O_2 production to dry matter content in initial soil sample.

6. Results

Soil samples were analyzed in laboratory of LDF Mendelu, Department of Geology and Pedology. Methods which were used are determination of soil granulometrical content, its physical and biochemical properties.

Profile No. 1

Location: N 52° 23’ 52” E 16° 50’ 3”
Land use: Coniferous forest (pine)
Soil: Arenosol
Parent material: fluvioglacial sand (Würm glaciation)
Horizons description:
0 – 7 cm Ol, grey, pine needles, cones and twigs
7 – 23 cm A, grey fresh loose sand, without skelet, granular structure, dry, pH in H_2O 3,62, pH in KCl 3,66
23 – 52 cm AC, gray-yellow, with rusty coating, fresh sand loose, slightly moist, very slightly skeletal (1% stones and gravel glacial) with granular structure pH in H_2O 3.5, pH in KCl 3,59
52 – 100 cm C, Fresh sand loose, separated, granular structure, very slightly skeletal (1% stones and gravel glacial), slightly moist, pH in H_2O 3,8, pH in KCl 4,18
Soil description
Type: **arenosol**
Subtype: **Haptic Arenosol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **sandy material with individual grains of gravel and small stones**

Soil profile is characterized by its huge contents of sand. In whole profile, sand (2 – 0,05 mm) took more than 96% of total granulometrical composition. However, in the deepest horizon, percentage of sand equals to 92% due to occurrence of several bigger stones. Trophism of that soil is connected with forest management targeted on pine. Moreover, according to water regime, granulometrical composition and lower amount of nutrients was decided to use this soil in connection of pine forests.

Soil properties description

Horizonts			A	AC	C
Depth of horizonts in cm			7 - 23	23 - 52	52 - 100
Granulometry		Volume in %			
1. Gravel	> 2 mm		0,6	1,14	5,64
2. Sand	2,0 - 0,05 mm		96,86	96,43	92,23
3. Silt	0,05 - 0,002 mm		0,88	1,16	0,87
4. Clay	< 0,002 mm		0,8	0,8	0,87
Physical soil properties					
„Wet" bulk density - ρ_w		g/cm³	1,78	1,82	1,77
Bulk density - s		%	93,05	87,53	91,26
Dry mass (mass of oven-dry soil) - ρ_d		g/cm³	1,59	1,5	1,54
Gravimetric water content - w		%	6,95	12,47	8,74
Volumetric water content - Θ		%	11,01	18,64	13,45
Porosity (percent of pore space) - P		%	72,25	41,38	63,72
Aeration - A		%	61,19	22,74	50,28
Pores saturation - Rnp		%	15,22	45,08	21,11
Specific gravity of soil - ρ_s		g.cm³	5,72	2,55	4,24
pH in H_20 or KCl					
pH in H_20			3,66	3,59	4,18
pH in KCl			3,62	3,50	3,8
Soil catalase activity (ml O_2.5.g.15 min.)			> 5	>5	>5

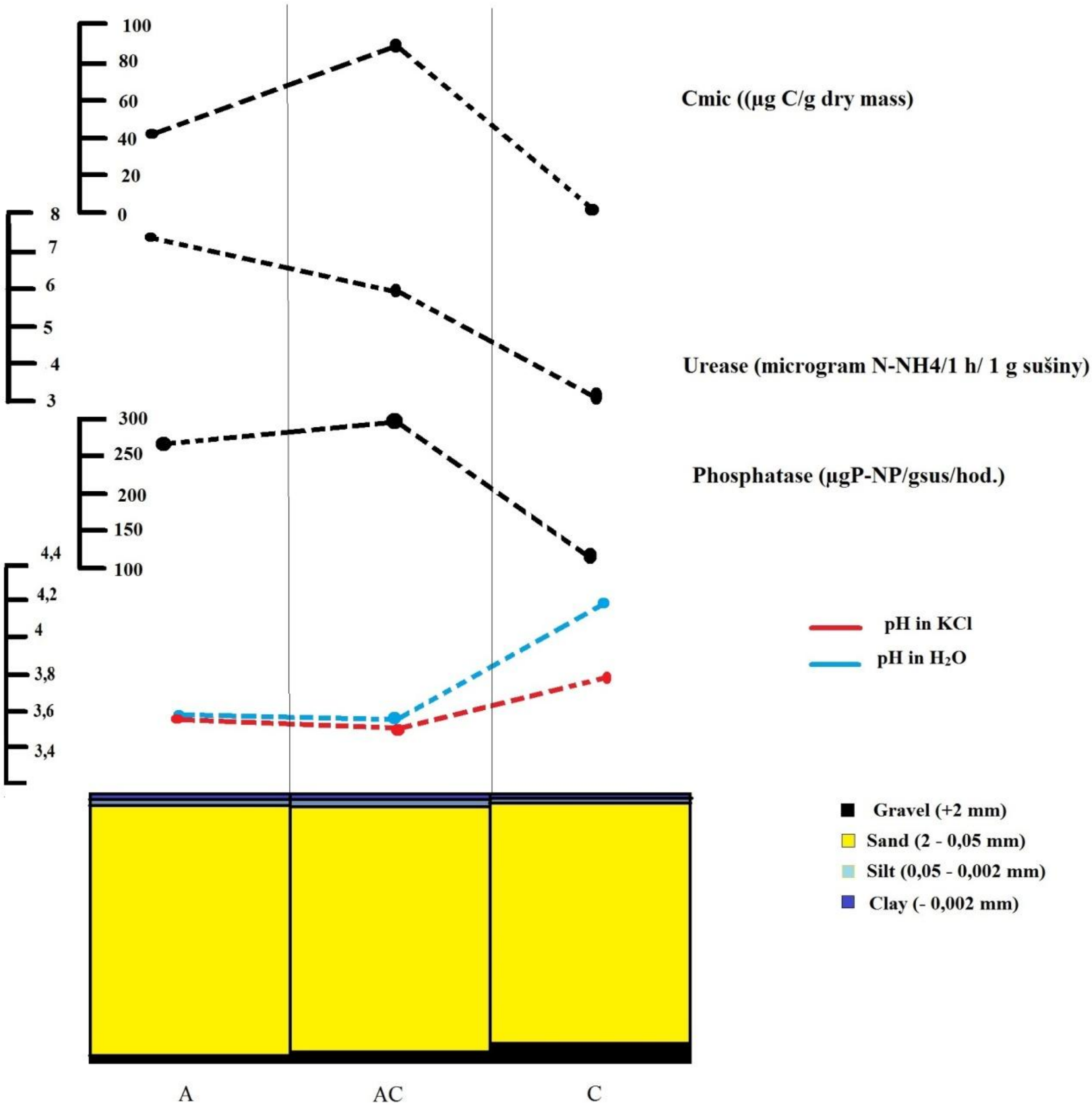
Profile No.1 (biochemical properties)				
Horizons		**A**	**AC**	**C**
Phosphatase (µgP-NP/gsus/hod.)		267.02	299.24	111.31
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		7.19	5.81	2.66
Cmic (µg C/g dry sample)	**Max**	138.92	140.80	9.60
	Min	43.28	93.47	0.75
	Avg.	103.83	118.88	1.63

Profile no.1 can be described as sandy soil. Weight of dry soil sample in horizon A was 564.92g. Amount of sandy particles is equal to 96.86%. Other values were 0.60% for Gravel, 1.88% for Silt and 0.52% for Clay. Weight of dry soil sample in horizon AC was 552.52g. Amount of sandy particles is equal to 96.43%. Other values were 1.14% for Gravel, 1.16% for Silt and 0.80% for Clay. Compare to horizon A in Profile No.1, deeper horizon AC shows a decreasing amount of sand and silt fraction and increasing amount of gravel and clay fractions. There is an increasing of gravel in soil caused by occurrence of few bigger stone. Weight of dry soil sample in horizon C was 560.97g. Amount of sandy particles is equal to 92.23%. Other values were 5.64% for Gravel and same value for 0.87% for Silt and Clay. Compare to both previous horizons in Profile No.1, the deepest horizon C shows the highest amount of sand and silt fraction and less amount of gravel and clay fractions. There is an increasing of gravel in soil caused by occurrence of few bigger stone.

Profile No.1, horizon A is determined according to soil reaction as strongly acid. In pH/H_20 in horizon C, there is a value 4.18. Due to its measurement, horizon C may be described as medium acid. Trend of values have a decreasing character from A to AC horizon, from that point is increasing to C horizon. Minimal value of measurement was measured in horizon AC, where pH in H_2O reached 3.59 and pH in KCl was equal to 3.5.

Profile No.1, is determined by its biochemical properties as well. Activity of soil phosphatases (μgP-NP/gsus/hod.) is increasing from horizon A (267.02) to horizon AC (299.24). From horizon AC trend of value has a decreasing character and the value of phosphatise activity is equal to 111.31 in horizon C. There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile. The highest amount of produced N-NH4 is situated in horizon A (7.19), horizon AC (5.81) and horizon C (2.66). Activity of Cmic (μg C/g dry sample) is increasing from horizon A to horizon AC. From horizon AC trend of value has a decreasing character and the value of phosphatise activity is equal to in horizon C.

Scheme no. 1, Profile no.1



Profile No. 2

Location: N 52° 24' 37" E 16° 47'24"
Land use: Not used
Soil: Arenosol
Parent material: fluvioglacial sand (Würm glaciation)
0 – 5 O, decomposed organic matter
5 – 28 cm A, grey fresh loose sand, without skelet, weak strukture, texture is sandy with < 1% of clay fraction, dry, pH in H_2O 5,53, pH in KCl 5,25
28 – 110 cm C, yellow-greyish, fresh sand, weak structure, texture is sandy with < 1% of clay fraction, slightly moist, pH in H_2O 4,95, pH in KCl 4,76

Soil diagnostic
Type: **Arenosol**
Subtype: **Haptic Arenosol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **sandy material with individual grains of gravel and small**

Soil profile is located on unused land along road going to Poznań. Whole land is covered by grass and pioneer trees as *Betula spp*. and *Popolus spp.*. Considering influence of grass cover the pH level is higher than in Profile 1.

Soil properities description

Horizonts		A	C
Depth of horizonts in cm		7 - 28	28 - 110
Granulometry	Volume in %		
1. Gravel > 2 mm		11,23	6,54
2. Sand 2,0 - 0,05 mm		84,93	92,40
3. Silt 0,05 - 0,002 mm		1,79	0,22
4. Clay < 0,002 mm		1,79	0,22
Physical soil properties			
„Wet" bulk density - ρ_w	g/cm³	1,90	1,81
Bulk density - s	%	88,97	88,72
Dry mass (mass of oven-dry soil) - ρ_d	g/cm³	1,60	1,51
Gravimetric water content - w	%	11,03	11,28
Volumetric water content - Θ	%	17,66	17,13
Porosity (percent of pore space) - P	%	53,95	32,71
Aeration - A	%	36,29	15,58
Pores saturation - Rnp	%	32,96	54,64
Specific gravity of soil - ρ_s	g.cm³	3,47	2,24
pH in H_20 or KCl			
pH in H_20		5,53	4,95
pH in KCl		5,25	4,76
Soil catalase activity (ml O2.5.g.15 min.)		> 5	>5

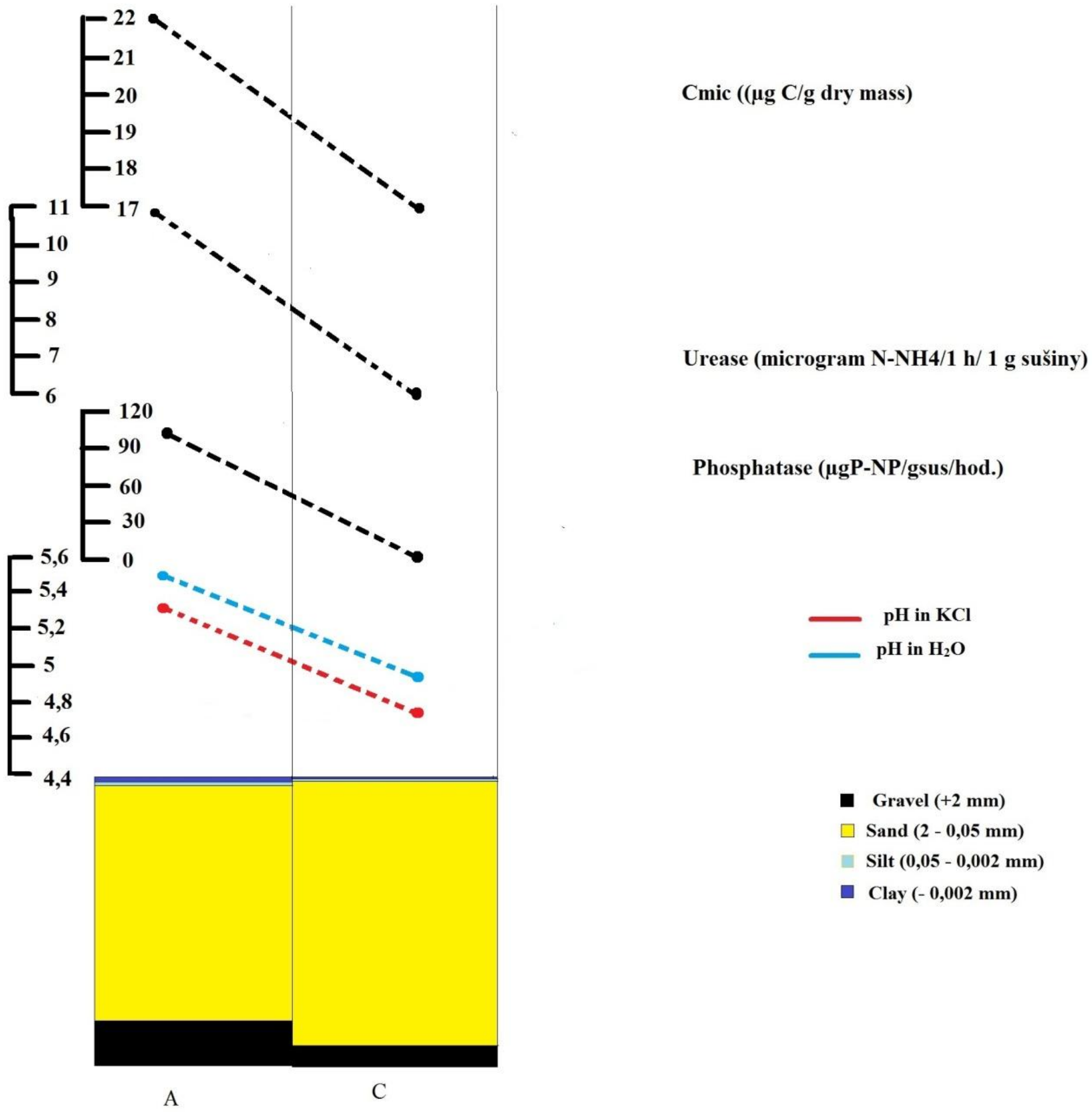
Profile No.2 (biochemical properties)			
Horizons		**A**	**AC**
Phosphatase (µgP-NP/gsus/hod.)		108.94	6.50
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		10.89	5.94
Cmic (µg C/g sušiny)	**Max**	79.34	19.51
	Min	21.88	17.45
	Avg.	21.88	17.91

During determination of soil granulometrical content were calculated amount of individual soil fractions as Gravel, Sand, Silt and Clay. Profile No.1 might be described as sandy soil. Weight of dry soil sample was 563.67g. Amount of sandy particles is equal to 84.93%. Other values were 11.23% for Gravel, 2.54% for Silt and 1.23% for Clay. Profile No.2 might be described as sandy soil. Weight of dry soil sample was 552.98g. Amount of sandy particles is equal to 92.40%. Other values were 6.54% for Gravel, 0.62% for Silt and 0.22% for Clay. Compare to Profile No.1, this profile shows a decreasing amount of sand, silt and clay fractions. There is a rapid increasing of gravel in soil, which increase from 5.64% in Profile No.1 to 11.23% in horizon A and 6.54% in horizon C in Profile No.2. It caused by occurrence of few bigger stone up to 5 grams.

Profile No.2 is determined according to soil reaction as Medium acid and Slighty acid in H_2O and Medium acid in KCl. Values are higher than in previous profile. Trend of values have a decreasing character from A to C horizon. Minimal value of measurement was measured in horizon C, where pH in H_2O reached 4.95 and pH in KCl was equal to 4.76.

Profile No.2, is determined by its biochemical properties as well. Activity of soil phosphatases (µgP-NP/gsus/hod.) is decreasing from horizon A (267.02) to horizon C. Phosphatise activity is equal to 6.50 in horizon C. There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile. The highest amount of produced N-NH4 is situated in horizon A (10.89) and horizon C (5.94). Activity of Cmic (µg C/g dry sample) is increasing from horizon A to horizon C as well.

Scheme no. 2, Profile no.2



Profile No. 3

Location: 52°30'28.1"N 16°49'10.4"E
Land use: stubble after triticale
Soil: Arenosol
Parent material: fluvioglacial sand (Würm glaciation)
0 – 2 O, crop seeds and fertilizer
2 - 30 cm Ap, grey with yellow veins, sandy texture, without skelet, weak strukture, dry, pH in H_2O 5.31 pH in KCl 5.23
30 – 60 cm AC yellow-greish, sandy structure, weak structure, slightly moist, pH in H_2O 4.59, pH in KCl 4.19
60 – 80 cm C, yellow-orange, sandy texture, weak structure, slightly moist, pH in H_2O 3.87, pH in KCl 3.16
Soil diagnoza
Type: **Arenosol**
Subtype: **Haptic Arenosol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **sandy material with individual grains of gravel and small**

Presented soil profile no. 3 was found on field near town Zlotkowo. Land belongs to private owner. Previous crop on field was specify as triticale (*x Triticosecale*). There are soils used only for crop production because there are no rocks find in soil body. Colour variability of soil starts on grey, moving deeper changed to yellow up to light orange.

Soil properities description

Horizonts		Ap	C1	C2
Depth of horizonts in cm		2 - 30	30 - 60	60 - 80
Granulometry	Volume in %			
1. Gravel > 2 mm		4,25	2,58	2,18
2. Sand 2,0 - 0,05 mm		89,35	94,09	95,17
3. Silt 0,05 - 0,002 mm		3,86	2,65	1,66
4. Clay < 0,002 mm		2,03	0,26	0,43
Physical soil properties				
„Wet" bulk density - ρ_w	g/cm³	1,58	1,75	1,73
Bulk density - s	%	97,36	98,01	98,09
Dry mass (mass of oven-dry soil) - ρ_d	g/cm³	1,51	1,69	1,68
Gravimetric water content - w	%	2,64	1,99	1,91
Volumetric water content - Θ	%	3,93	3,37	3,21
Porosity (percent of pore space) - P	%	45,44	42,05	37,36
Aeration - A	%	41,49	38,68	34,15
Pores saturation - Rnp	%	8,88	8,04	8,61
Specific gravity of soil - ρ_s	g.cm³	2,76	2,92	2,68
pH in H_20 or KCl				
pH in H_20		5,31	4,59	3,87
pH in KCl		5,23	4,19	3,16
Soil catalase activity (ml O_2.5.g.15 min.)		> 5	>5	>5

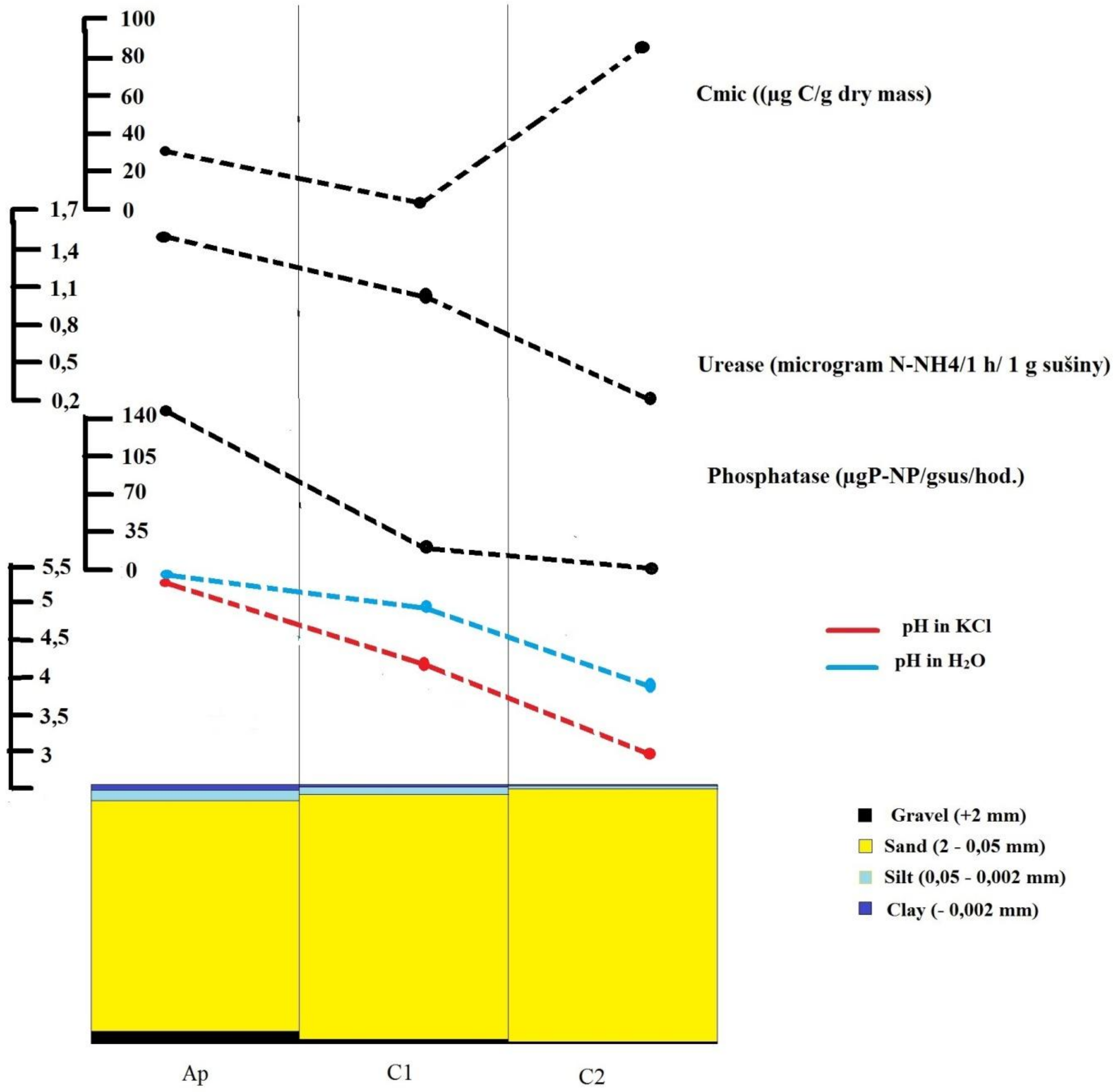
Profile No.3 (biochemical properties)				
Horizons		**Ap**	**C1**	**C2**
Phosphatase (µgP-NP/gsus/hod.)		145.38	12.55	4.71
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		1.42	0.91	0.27
Cmic(µg C/g sušiny)	**Max**	46.51	10.70	114.52
	Min	31.73	7.47	84.77
	Avg.	41.17	10.18	85.81

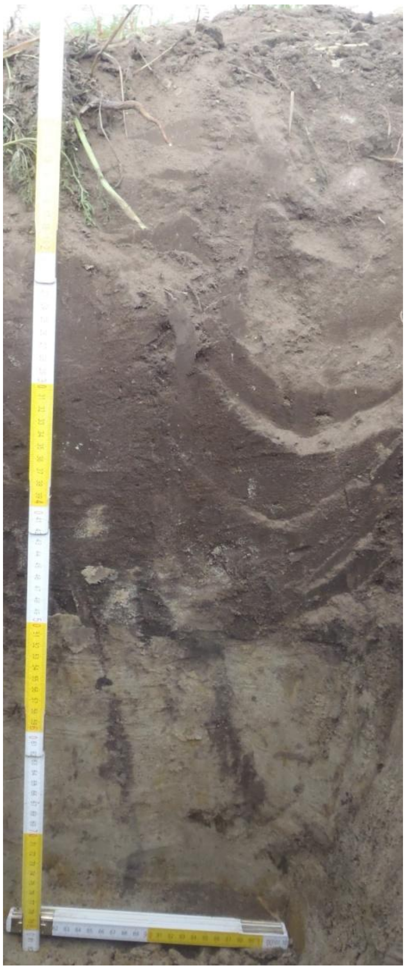
Profile No.3, horizon Ap might be described as sandy soil. Weight of dry soil sample was 249.33g. Amount of sandy particles is equal to 89.35%. Other values were 4.25% of Gravel and same value for 3.86% of Silt and 2.03% of Clay. Amount of gravel in soil is presented by occurrence of few bigger stones. Horizon C1 might be described as sandy soil. Weight of dry soil sample was 251.54g. Amount of sandy particles is equal to 94.09%. Other values were 2.58% of Gravel, 2.65% of Silt and 0.26% of Clay. Compare to horizon Ap, deeper horizon C1 shows a decreasing amount of gravel, silt and clay fraction and there is an increasing of gravel in soil caused by occurrence of few bigger stone. Horizon C2 might be described as sandy soil. Weight of dry soil sample was 216.31g. Amount of sandy particles is equal to 95.17%. Other values were 2.18% of Gravel, 1.66% of Silt and 0.43% of Clay. Compare to both horizons, the deepest horizon C2 reflects a decreasing amount of gravel and silt fraction. Moreover, there is a increasing of clay fraction.

Profile No.3 is determined according to soil reaction from slightly acidic to strongly acidic. It is caused by high amount of acidic minerals like quartz etc. Trend of values have a decreasing character in whole profile. Minimal value of measurement was measured in horizon C, where pH in H_2O reached to 3.86 and pH in KCl was equal to 3.15.

Profile No.3, is determined by its biochemical properties as well. Activity of soil phosphatases (µgP-NP/gsus/hod.) is decreasing in whole profile. The highest activity is determined in horizon Ap (145.38). There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile. The highest amount of produced N-NH4 is situated in horizon Ap (1.42), horizon C1 (0.91) and horizon C2 (0.27). Activity of C_{mic} (µg C/g dry sample) is decreasing from horizon Ap to horizon C1. From horizon C1 trend of value has an increasing character.

Scheme no. 3, Profile no.3





Profile No. 4

Location: N 52°30'30.9" E 16°49'06.0"
Land use: stubble after triticale
Soil: Fluvisol
Parent material: fluvioglacial sand (Würm glaciation)
0 – 4 cm O organic matter
4 – 28 cm Ap, grey, loamy sand texture, modreate structure, slightly moist, pH in H_2O 7.33, ph in KCl 7.19
28 – 50 cm A1, grey-dark loamy sand texture, without skelet, moderate structure, slightly moist, pH in H_2O 7.18, pH in KCl 6.88
50 – 80 cm C grey with dark veins, sandy texture, weak structure, moist, pH in H_2O 7.35, pH in KCl 6.29
Soil description
Type: **Fluvisol**
Subtype: **Gleyic Fluvisol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **sandy material with individual grains of gravel and small**

Last soil profile described in Poland. Location of soil body is 500 metres from Profile No.3. Comparing of all polish profile, probably this is the most fertile soil used in diploma thesis. There was an important influence of water which formed a gleyic horizon located bellow 50 cm. Second important role is presented in terrain configuration where a fertile organic material was accumulated and forms chernic layer in profile.

Soil properities description

Horizonts		Ap	A2	C
Depth of horizonts in cm		7 - 28	28 - 50	50 - 80
Granulometry	Volume in %			
1. Gravel > 2 mm		2,73	5,47	4,84
2. Sand 2,0 - 0,05 mm		89,20	91,51	91,76
3. Silt 0,05 - 0,002 mm		5,49	2,98	3,21
4. Clay < 0,002 mm		0,93	0,8	0
Physical soil properties				
„Wet" bulk density - ρ_w	g/cm³	1,84	1,94	1,99
Bulk density - s	%	92,91	90,38	93,22
Dry mass (mass of oven-dry soil) - ρ_d	g/cm³	1,65	1,67	1,78
Gravimetric water content - w	%	7,09	9,62	6,78
Volumetric water content - Θ	%	11,69	16,11	12,09
Porosity (percent of pore space) - P	%	23,80	41,30	44,22
Aeration - A	%	12,12	25,19	32,14
Pores saturation - Rnp	%	50,08	39,04	27,48
Specific gravity of soil - ρ_s	g.cm³	2,16	2,85	3,19
pH in H_20 or KCl				
pH in H_20		7,33	7,18	7,35
pH in KCl		7,19	6,88	6,29
Soil catalase activity (ml O_2.5.g.15 min.)		> 5	>5	>5

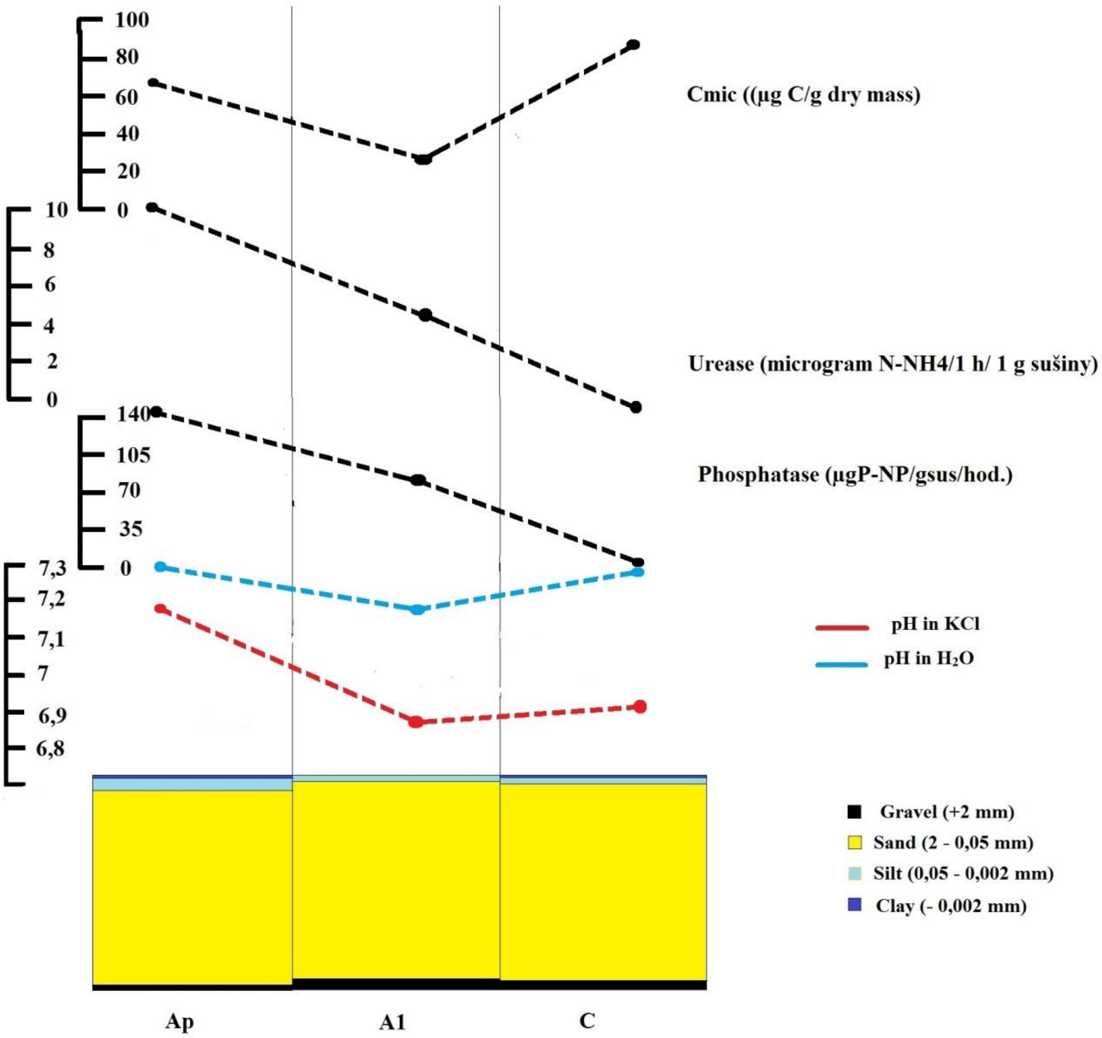
Profile No.4 (biochemical properties)				
Horizons		**Ap**	**A1**	**C**
Phosphatase (µgP-NP/gsus/hod.)		141.16	85.54	18.98
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		10.52	4.99	0.58
Cmic(µg C/g sušiny)	**Max**	81.69	45.93	104.63
	Min	67.74	32.61	87.33
	Avg.	69.39	35.77	90.61

Profile No.4, horizon Ap might be described as sandy soil. Weight of dry soil sample was 216.31g. Amount of sandy particles is equal to 89.20%. Other values were 2.73% of Gravel and same value for 5.49% of Silt and 0.93% of Clay. Amount of gravel in soil is presented by occurrence of few bigger stone. Horizon C1 might be described as sandy soil. Weight of dry soil sample was 217.43g. Amount of sandy particles is equal to 91.51%. Other values were 5.47% of Gravel, 2.98% of Silt and 0.04% of Clay. Compare to horizon Ap, deeper horizon A1 shows a decreasing amount of silt and clay fraction and there is an increasing of gravel. Horizon C might be also described as sandy soil. Weight of dry soil sample was 218.04g. Amount of sandy particles is equal to 91.76%. Other values were 4.84% of Gravel, 3.21% of Silt and 0.19% of Clay. Compare of whole profile, the deepest horizon C shows the highest amount of sandy particles. Gravel particles have an increasing trend in horizon Ap to A1, from this point, the volume of gravel is slightly decreasing. Trend of silt distribution in soil has decreasing character from horizon Ap to A1 where it turned to increasing character. By the same distribution clay could by describe.

Profile No.4 is determined according to soil reaction as slightly alkaline in H_2O and neutral in KCl. Trend of values have a decreasing character in horizons Ap and A1. From A1 to C trend is changing its character to increasing one. Minimal value of measurement was measured in horizon A1, where pH in H_2O reached to 7.18 and pH in KCl was equal to 6.88.

Profile No.4, is determined by its biochemical properties as well. Activity of soil phosphatases (µgP-NP/gsus/hod.) is decreasing in whole profile. The highest value is found in horizon Ap (141.16). There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile as well. The highest amount of produced N-NH4 is situated in horizon A (10.52), horizon AC (4.99) and horizon C (0.58). Activity of C_{mic} (µg C/g dry sample) is decreasing from horizon Ap to horizon A1. From horizon AC trend of value has a increasing character and the value of phosphatise activity is equal to in horizon C.

Scheme no. 4, Profile no.4



Profile No. 5

Location: N 49° 59’ 13” E 18° 6’ 2”
Land use: sown oilseed rape
Soil: Arenosol
Parent material: fluvioglacial sand (Riss I glaciation)
0 – 3 cm O oil rape seeds and fertilisor
3 – 7 cm A, grey, loamy sand texture, moderate structure, slighty moist, pH in H_2O 8.16, pH in KCl 7.75
7 – 23 cm Ap, yellow-gray, sandy texture, without skelet, weak strukture, slighty moist, pH in H_2O 8.11, pH in KCl 7.14
52 – 100 cm C, yellow, sandy texture, weak structure, slightly moist, pH in H_2O 8.75, pH in KCl 6.98

Soil description
Type: **Arenosol**
Subtype: **Albic arenosol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **light loess material with individual grains of gravel and small stones**

Profile no. 5 describes an arable land on glaciofluvial parent material in Czech Republic. Comparing to terrain configuration, Chuchelná town is located in subunit called Poopavská Lowland with small hills.

Soil profile description

Horizonts		A	Ap	C
Depth of horizonts in cm		7 - 23	23 - 52	52 - 100
Granulometry	Volume in %			
1. Gravel > 2 mm		0,61	0,25	0,05
2. Sand 2,0 - 0,05 mm		87,86	91,65	95,90
3. Silt 0,05 - 0,002 mm		6,98	6,67	3,26
4. Clay < 0,002 mm		4,47	1,21	0,42
Physical soil properties				
„Wet" bulk density - ρ_w	g/cm³	1,59	1,84	1,80
Bulk density - s	%	94,40	94,13	91,26
Dry mass (mass of oven-dry soil) - ρ_d	g/cm³	1,43	1,65	1,65
Gravimetric water content - w	%	5,60	5,88	4,84
Volumetric water content - Θ	%	8,03	9,71	7,96
Porosity (percent of pore space) - P	%	46,50	31,58	31,43
Aeration - A	%	38,47	21,73	23,46
Pores saturation - Rnp	%	17,29	31,13	25,39
Specific gravity of soil - ρ_s	g.cm³	2,68	2,4	2,53
pH in H_20 or KCl				
pH in H_20		8,16	8,11	7,85
pH in KCl		7,75	7,14	6,97
Soil catalase aktivity (ml O_2.5.g.15 min.)		20	>5	>5

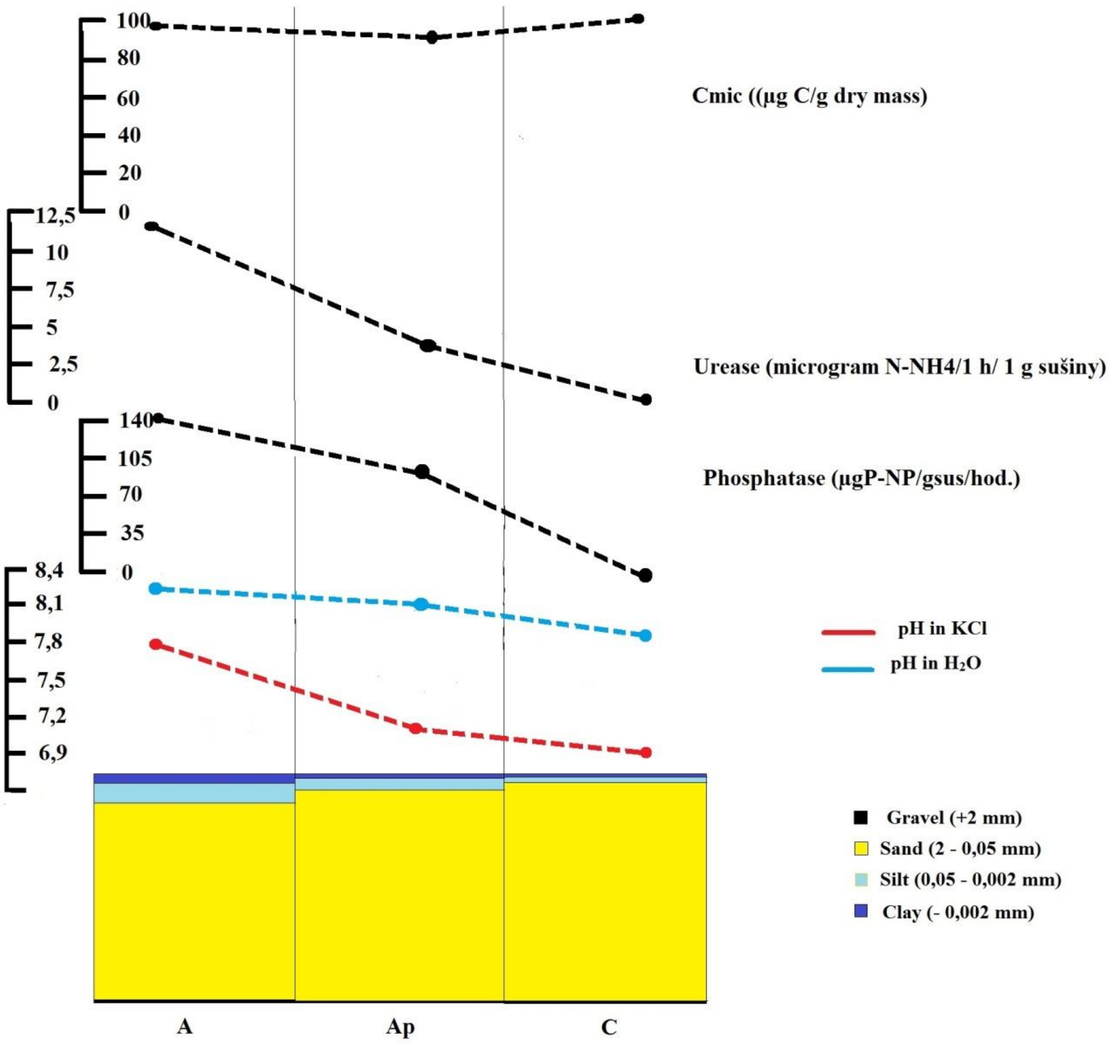
Profile No.5 (biochemical properties)				
Horizons		**A**	**Ap**	**C**
Phosphatase (µgP-NP/gsus/hod.)		84.35	58.85	76.4
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		11.02	4.51	0.80
Cmic(µg C/g sušiny)	**Max**	127.22	99.44	112.15
	Min	101.46	97.66	104.22
	Avg.	112.15	97.87	106.47

Profile No.5, horizon A might be described as sandy soil. Soil sample was taken near Chuchelná town on arable land. Weight of dry soil sample was 289.54g. Amount of sandy particles is equal to 87.86%. Other values were 0.61% for Gravel, 6.98% for Silt and 4.47% for Clay. Horizon Ap might be described as sandy soil. Weight of dry soil sample was 429.8g. Amount of sandy particles is equal to 91.65%. Other values were 0.25% for Gravel, 6.67% for Silt and 1.21% for Clay. Horizon C might be also described as sandy soil. Weight of dry soil sample was 458.52g. Amount of sandy particles is equal to 95.90%. Other values were 0.05% of Gravel, 3.26% of Silt and 0.42% of Clay. Compare of whole profile, the deepest horizon C shows the highest amount of sandy particles. Gravel silt and clay particles have a decreasing trend in whole profile.

Profile No.5 is determined according to soil reaction as slightly alkaline in H_2O and slightly alcaline to neutral reaction in KCl. Both of trends of values have a decreasing character in whole profile. Maximal value in H_2O was measured in horizon A, 8.16 and in KCl the value is also in A horizon, 7.74. Minimal value of measurement was measured in horizon C, where pH in H_2O reached to 7.84 and pH in KCl was equal to 6.97.

Profile No.5, is determined by its biochemical properties as well. Activity of soil phosphatases (μgP-NP/gsus/hod.) is decreasing from horizon A (84.35) to horizon Ap (58.85). From horizon Ap trend of value has a increasing character and the value of phosphatise activity is equal to 76.4 in horizon C. There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile. The highest amount of produced N-NH4 is situated in horizon A (11.02), horizon Ap (4.51) and horizon C (0.80). Activity of Cmic (μg C/g dry sample) is decreasing from horizon A to horizon Ap. From horizon Ap trend of value has an increasing character and the value of phosphatise activity is equal to in horizon C.

Scheme no. 5, Profile no.5



Profile No. 6

Location: N 49° 58’ 85” E 18° 05’84”
Land use: Coniferous forest (pine)
Soil: Podzol
Parent material: fluvioglacial sand (Riss I glaciation)
0 – 5 Ol pine needles, cones and twigs
5 – 18 cm A, yellow-grey, texture sandy < 1% of clay fraction, weak structure, dry, pH in H_2O 4.19, pH in KCl 3.29
18 – 38 cm A1, grey-yellow, sandy texture with < 1% of clay fraction , without skelet, weak strukture, dry, pH in H_2O 4.65, pH in KCl 4.01
38 – 70 cm AC, light yellow, sandy texture with < 1% of clay fraction, dry, very slightly skeletal (1% stones and gravel glacial), weak structure pH in H_2O 4.52, pH in KCl 4.06
70 – 100 cm C, light yellow, sandy texture with < 1% of clay fraction, weak structure, dry, very slightly skeletal (1% stones and gravel glacial) pH in H_2O 4.54, pH in KCl 4,11
Soil description
Type: **Fluvisol**
Subtype: **not stratified Fluvisol**
Variety subtype: **aeolian**
Type: **water-glacial sand dune formations**
Genre: **light loess material with individual grains of gravel and small stones**

Second profile in czech conditions is situated in pine forest approximatelly 25 metres from road going to Bolatice. Next to pine stand there is a several stripes of planted oak. Due to high acidity conditions the herb layer is represented by mores and acidophilic grasses.

Soil Profile description

Soil properities in soil profile no. 6					
Horizonts		A	A1	AC	C
Depth of horizonts in cm		5 - 18	18 - 38	38 - 70	70 - 100
Granulometry	Volume in %				
1. Gravel > 2 mm		8,42	7,00	7,17	3,64
2. Sand 2,0 - 0,05 mm		82,81	88,89	89,16	94,02
3. Silt 0,05 - 0,002 mm		7,27	3,38	1,47	0,85
4. Clay < 0,002 mm		1,32	0,46	1	0,63
Physical soil properties					
„Wet" bulk density - ρ_w	g/cm³	1,44	1,50	1,55	1,51
Bulk density - s	%	97,35	97,66	98,79	98,96
Dry mass (mass of oven-dry soil) - ρ_d	g/cm³	1,36	1,44	1,52	1,47
Gravimetric water content - w	%	2,65	2,35	1,21	1,04
Volumetric water content - Θ	%	3,6	3,36	1,83	1,53
Porosity (percent of pore space) - P	%	46,19	45,00	43,67	48,96
Aeration - A	%	42,59	41,63	41,83	47,43
Pores saturation - Rnp	%	7,81	7,49	4,19	3,12
Specific gravity of soil - ρ_s	g.cm³	2,53	2,61	2,69	2,89
pH in H_20 or KCl					
pH in H_20		4,19	4,65	4,52	4,54
pH in KCl		3,39	4,01	4,06	4,11
Soil catalase activity (ml O_2.5.g.15 min.)		>5	>5	>5	>5

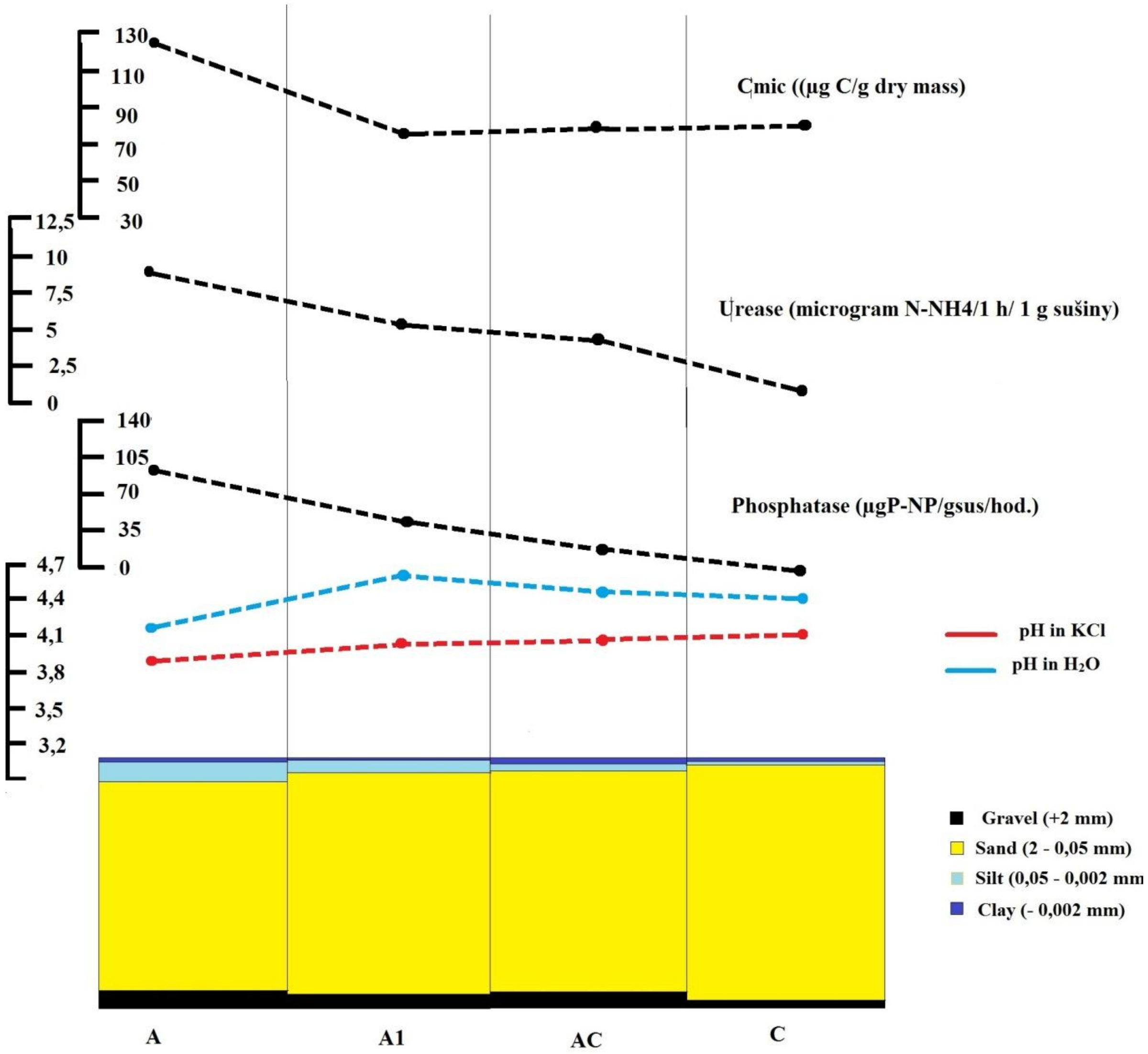
Profile No.6 (biochemical properties)					
Horizons		**A**	**A1**	**AC**	**C**
Phosphatase (µgP-NP/gsus/hod.)		86.13	40.57	18.3	9.72
Ureases (microgram N-NH4/1 h/ 1 g dry sample)		8.39	5.17	3.57	1.64
Cmic(µg C/g sušiny)	**Max**	136.97	84.62	98.31	94.23
	Min	126.07	77.20	87.57	87.42
	Avg.	134.88	83.42	92.22	89.69

Profile No.6, horizon A might be described as sandy soil. Soil sample was taken near Chuchelna town in pine forest stand. Weight of dry soil sample was 353.37g. Amount of sandy particles is equal to 82.81%. Other values were 8.42% for Gravel, 7.27% for Silt and 1.32% for Clay. Horizon A1 might be described as sandy soil. Weight of dry soil sample was 369.84g. Amount of sandy particles is equal to 88.89%. Other values were 7.00% for Gravel, 3.38% for Silt and 0.46% for Clay. Horizon AC might be described as sandy soil. Weight of dry soil sample was 376.47g. Amount of sandy particles is equal to 89.16%. Other values were 7.17% for Gravel, 1.47% for Silt and 2% for Clay. Horizon C might be also described as sandy soil. Weight of dry soil sample was 459.87g. Amount of sandy particles is equal to 94.02%. Other values were 3.64% of Gravel, 0.85% of Silt and 0.63% of Clay. Compare of whole profile, the deepest horizon C shows the highest amount of sandy particles. Different distribution of gravel and clay particles is described by changing in whole profile. From horizon A to A1 amount of gravel is decreasing. From horizon A1 there is an increasing trend to horizon AC but from that point, the value of gravel particles is decreasing. Silt particles have a decreasing trend in whole profile.

Profile No.6 is determined according to soil reaction as medium acidic in H_2O and strongly acidic in KCl. Both of trends of values have a different character in whole profile. Soil reaction in H_2O has an increasing character from horizon A to A1. From that horizon curve of pH change its character by decreasing its value. Soil reaction in KCl has an increasing character in whole profile. Maximal value in H_2O was measured in horizon A1, 4.65 and in KCl the value is in C horizon, 4.11. Minimal value of measurement was measured in horizon A, where pH in H_2O reached to 4.19 and pH in KCl was equal to 3.39.

Profile No.6, is determined by its biochemical properties as well. Activity of soil phosphatases (μgP-NP/gsus/hod.) is decreasing in whole profile. There is a decreasing character of ureases activity (microgram N-NH4/1 h/ 1 g dry sample) in whole profile as well. The highest amount of produced N-NH4 is situated in horizon A (8.39), horizon A1 (5.17) and horizon AC (3.57) and C (1.64). Activity of Cmic (μg C/g dry sample) is decreasing from horizon A to horizon A1. From horizon A1 trend of value has an increasing character to horizon AC and there is a decreasing trend of values from horizon AC to horizon C.

Scheme no. 6, Profile no.6



7. Discussion

According to granulometrical analyses, profiles may be described as typical sandy soil (82 – 96 % of sand particles), where sand particles (0.05–2.0 mm) appear as a major constituent. Jankowski et al. (2011) determined that mineral soil horizons developed in Pleistocene. Glaciofluvial materials have an extremely sandy texture with 88–100% content of 0.05–2.0 mm sand fraction. Clay and silt contents do not exceed 6 % and 4 % respectively. Bryk (2016) also confirmed, that studied podzols and arenosols are characterized by sandy textures, wherein the sand fraction also predominated. Glaciers that transported great volumes of mineral material are identified as the main pedogenetic causatives. Transferred material was accumulated in layers subsequently to the glacial meltdown and led to the development of sandy soils.

Chemical reaction is reported to be primarily in the acidic part of pH scale. Examined forest and unmanaged land soil profiles show highly acidic reaction, which is caused by acidic parent material. In contrast, the pH values of arable land show slightly alkaline reaction. Such soils are subjected to organic matter as well as green and synthetic fertilizer addition. Also more favourable conditions (rainsfalls, light) occur. Jankowski et al. (2011) shows, that investigated soils on glacifluvial parent material show acid to slightly acid reaction in top horizons and pH values tend to be higher in the upper parts of the sloped terrain (6.4 in H_2O and 6.0 in KCl) than in the lower parts (5.0 in H_2O and 4.5 in KCl). There are some possible explanations of the differences between these results. Jankowski could have analyzed soils from more fertile places (e.g. mixed forest, field with higher amount of organic matter, etc.) than soils presented in this thesis. Waroszewski et al. (2013) found that all horizons within the soil profiles had a strong acid reaction manifested by pH values ranging from 3.0 to 4.4.

Soil properties are also represented by certain biochemical indicators. Soils can be described by analyses of phosphatase (annex no.3) and urease activity (annex no.4) and microbial carbon content (annex no.2). Measured values of phosphatase activity on forest free areas show that the amount of spent μgP-NP is decreasing with soil depth. Polish profile on forested areas shows abnormal phosphatase activity where values in deeper horizons had increasing trend (267.02 – 299.24 – 111.31 μgP-NP/g dry mass/hod.). Yu et al. (2006) studied surface runoff phosphorus (P) loss in relation to phosphatase activity and soil P fractions in Florida sandy soils under citrus production.

They found the acid phosphatase activity in the five sandy soils ranged from 94.6 to 156.7 mg phenol kg^{-1} $3h^{-1}$. In contrast to acid phosphatase activity, alkaline phosphatase activity (10.4–87.2 mg phenol kg^{-1} 3 h^{-1}) was obviously lower than the acid phosphatase activity. These results could probably be connected to lower pH values (3.66 – 3.59 – 4.18 in H_2O, 3.62 – 3.5 – 3.8 in KCl) in deeper horizons in sampled soil. As Rejšek (1991) describes ´´Phosphatase activity can be very high in such soils. Acid phosphomonoesterase predominates in soils with acidic reaction (optimal pH 4.5 – 6) and alkaline phoshomonoesterase in alkaline soils (with optimal pH of 9 – 10). Acid phoshomonoesterase is not only produced by microorganisms, but also by plant roots. Plant roots produce exudates that can contain these enzymes´´. Urease activity analyses show that the amount of N-NH_4 is decreasing in all profiles with soil depth. Analyses of C_{mic} exhibit a decreasing trend in profiles in forest and unmanaged lands, but profiles on arable land show, that the highest values are recorded in the deepest horizons. Increased values carbon of microbial biomass in these horizons might be caused by stable anoxic environment where organic compounds were flooded by water. Other option could be occurrence of lower organic horizon, which was covered by sandy material later during the ice age. Amount of carbon in investigated soils reaches almost the same values as measured by Jankowski (2014). He found out that organic carbon content in organic horizons is higher in podzolic soils (220 – 550 $g \cdot kg^{-1}$) than in accumulative soils (160 – 480 $g \cdot kg^{-1}$). Eluvial and illuvial horizons of podzolic soils contain only about 9–11 $g \cdot kg^{-1}$ of C_{mic} to an analogous depth.

Czech and Polish soils were described by BPEJ classification. The results points to the fact that all studied soils have the same properties. They are located in the same climatic region, but on different parent material. Soils are situated on plane, having a deep soil profile and there are no stones in the soil body.

It is imperative that glacifluvial soils need to be cultivated and protected by different mechanisms compared to soils with higher clay and organic matter content. Soil under forest cover is managed as to achieve maximum protection by the canopy cover. Tree composition is dominated by Pine (*Pinus sylvestris*) with the admixture of Birch (*Betula pendula*), Beech (*Fagus sylvatica*) and Pedunculate oak (*Quercus robur*). Forest management is focused on supporting of admixtured trees, which have a major role for protection a soil against direct sun radiation, improve the soil environment by increasing nutrient content. Recommended management system used in described conditions is shelter cutting with all of its parameters. The selective harvest forest management is also recommended on such sites. Protective stripes should be left post harvest against strong winds and the decreasing in air humidity.

Other common problem that occurs at agricultural land is related to oversized fields. Current agricultural management is focused on producing single crops with very intensive cultivation of soil. Recommended methods for soil cultivation should be based on sustainability of agricultural environment, soil protection and accumulation of water in the landscape. Firstly, the area should be subdivided into smaller fields bordered by greenbelts with trees and shrubs, which may protect soil against erosion and improve microclimatic conditions of the field. Moreover, such precautions create conditions for the development of insectivores, which help with reduction of crop pests. Higher numbers of trees may increase the nutrient content in soil. There is also another important factor of crop management: current techniques are based on cultivation of wheat, rape and maize with the use of artificial fertilizers. This practise could potentially completely destroy the soil environment and increase the occurrence of pests. The best way of simple prevention is crop rotation with different crops per each year. All crop residues should be tilled into the soil after the harvest to increase the organic matter content in soil. Organic fertilizer such as manure or green plants of the *Fabaceae* family can also be used.

8. Conclusion

Diploma thesis is based on data extraction and personal experiences during study program in Poznań (Poland). It deals with comparison of selected soils on glacifluvial parent material, its granulometrical content, physical and biochemical properties. First part of thesis is aimed at description and comparison of glacial and interglacial periods in Czech Republic and Poland according glacier occurrence, its influence on land forming and sediments which were transported and accumulated after deglaciation.

There is a comparison of different land use and different soil classification systems between these countries as well. While glacier occurred twice per Pleistocene period in the Czech Republic, Poland was covered by ice practically entire. It was a reason that polish soils are very young developed than in Czech Republic. Also there are different classification systems. Czech soil classification system is based on Soil taxonomical classification system (TKSP) and Polish soil classification (SgP) as well. Moreover, there is a comparison of soils according to estimated pedological – ecological unit (BPEJ). Polish classification system which classified arable land is based on 6 basic groups, but it does not describe pedological and ecological conditions on site. Czech classification contains BPEJ code which described pedological and ecological conditions better than in previous system. All studied profiles were classified as soil with same properties.

Selected soils are studied and compared in this thesis. Samples were taken from two localities. Profiles No.1, 2, 3 and 4 were located around Poznań (Poland) and profiles no.5 and 6 were obtained around Chuchelna (Czech Republic). Profile No.1 and 2 were taken before growing season and profiles no.3 to 6 were taken after growing season. Soils of glaciofluvial origin are mainly described according to WRB classification as Arenosols. These soils are presented by high contents of sand particles cca.90% of total soil body. It is result of transported material during eight glacier periods. High occurrence of sand created from acid mineral (quartz) and rock (granite) caused very acid conditions in almost all profiles. Against that, profiles no. 4 and 5, pH is equal to slightly alkaline soil reaction. According to described soil reaction, soils are very active. Activity of biochemical conditions in soils is higher in these two profiles than in previous profiles as well. It is a result of higher amount of organic compounds.

These compounds occur only in top soil because there is horizon which is accumulated organic material.

This thesis might be used for studying of Polish and Czech glaciations. It makes for comparison of different soil classification systems, comparison of different land use, differences in soil classification systems etc. It may help to geological and pedological scientists with their research and scientific works.

9. Summary

In first part of thesis, there is a current literature focused on description of glacial and interglacial in Poland and Czech Republic. It deals with occurrence of glacier in each glacier era, glacier influence on landscape by erosion and accumulation, as well as formations after melted ice and soils, which were developed on glacifluvial parent material. Moreover, there is a description of land use and classification systems using in both countries.

In chapter called Material and methods, there is a description of used methods for samples collection and analyses for soil physical, chemical and biochemical properties. These samples were analysed according to methods created at Mendel University in Brno, Department of Geology and Pedology at Faculty of Forestry and Wood Technology.

Research was focused on comparison of selected soils on glacifluvial parent material on different land use. There were 4 samples taken from Poland and 2 samples in Czech Republic. There were soil survey target on granulometrical content, soil reactions, activity of soil catalase and activity of soil enzymes (phosphatises, ureases and microbial carbon content). Measured values were processed in tables and figures.

The research confirmed soils on glacifluvial parent material are described as sandy soils. Their reaction was identified as highly acidic because of compositions of parent material. Activity of soil enzymes were evaluated as very low, but samples from arable land were classified as highly active due to high occurrence of organic matter.

10. Refferences

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11. Annexes

11.1. BPEJ Description

Climate Region (X.xx.x.x)

Climate region as Vopratil, 2011 defined, includes area with identical climate conditions for agricultural crops growth and development. Climate regions were distinguished mainly for arable soil evaluation.

According to Quitt, 1971there are 9 climatic regions in Czech Republic. These regions are divided into three general groups:

- Warm (VT – T3)
- Mildly warm (MT1 – MT4)
- Cold (MCH and CH)

Main characteristics of individual regions are listed below:

0. **VT climate region** includes south part of Moravia (south and middle part of Dyjskosvratecký Úval, Pálavské Vrchy, Dolnomoravský Úval) and its occurrence is connected with Chernozems. It's an area best suitable to cultivate maize.
1. **T1 climate region** is located in the driest parts of Bohemia (Mostecká Pánev, around Žatec, in western part of Česká křídová pánev and western part of Pražská plošina on left bank of Vltava river.
2. **T2 climate region** is expanded in Middle Bohemia (from Vltava river to Kutná Hora) next to T1 climate region of Northwest Bohemia. In Morava, it occurred on Western and Northern part of Dyjskosvratecký Úval from Znojmo to Brno and Southern part of Vyškovská Brána.
3. **T3 climate region** takes Northern and Eastern part of Česká křídová pánev, whole Hornomoravský Úval and Eastern part of Boskovická Brázda.
4. **MT1 climate region** takes place in the largest part of Plzeňská vrchovina, in Morava this region is on South-east and in Moravian Highlands.
5. **MT2 climate region** is consisted of Bohemian and Moravian part. Bohemian part includes western, southern and eastern part of Plzeňská vrchovina, considerable part of Middle Bohemian highland, also Chebská, Sokolovská and

Budějovická Pánev. In Moravia there are parts of this region reaching in south-western part of Moravian highlands, higher altitudes of Boskovická brázda and Opavsko-Hlučínská vrchovina.

6. **MT3 climate region** appears in Moravská Brána, Ostravská Pánev, part of Podbeskydská vrchovina and small part of Frýdlantský výběžek.
7. **MT4 climate region** has a largest influence in the Czech Republic. It's located in all higher uplands and borders with MT2 region; it includes Tachovská brázda, Chodská vrchovina, part of Bohemian Benchland, Brdská vrchovina, the largest part of Moravian Benchland, Drahanská vrchovina, Vizovická vrchovina, Nízký Jeseník, Žulovská Upland etc.
8. **MCH climate region** takes all foothills above 550 m a.s.l.. It occurs in lower parts of Krušné Mountains and Český les, Šumavské předhůří, the highest parts of Středočeská vrchovina and Brdská pahorkatina, part of Moravian vrchovina, Bílé Karpaty, Javorníky and Hostýnské vrchy.
9. **CH climate region** is identical with mountains. It's distinguished arable land in all bordered mountains of Bohemia and Morava and Žďárské vrchy

Figure no.1, characterize a weather conditions in these climate regions (Středová, H., Chuchma, F., 2014).

Table No.1,**Climatic conditions in climate regions**

Code	Symbol	Characteristics	TS10		T avg		P avg		MC iv - ix		DP iv - ix	
			min	max	min	max	min	max	min	max	min	max
0	VT	Very warm, dry	2800	3100	9	10	500	600	30	50	0	3
1	T1	Warm, dry	2600	2800	8	9	0	500	40	60	0	2
2	T2	Warm, slightly dry	2600	2800	8	9	500	600	20	30	2	4
3	T3	Warm, slightly wet	2500	2800	7(8)	9	550	650 (700)	10	20	4	7
4	MT1	Slightly warm, dry	2400	2600	7	8,5	450	550	30	40	0	4
5	MT2	Slightly warm, Slightly dry	2200	2500	7	8	550	650 (700)	15	30	4	10
6	MT3	Slightly warm (to warm), wet	2500	2700	7,5	8,5	700	900	0	10	0	10
7	MT4	Slightly warm, wet	2200	2400	6	7	650	750	5	15	0	10
8	MCH	Slightly cold, wet	2000	2200	5	6	700	800	0	5	0	10
9	CH	Cold, wet	0	2000	0	5	0	800	0	0	0	10

Legend: TS10 [◦C] – Air temperature sum above 10 ◦C, TAVG [◦C] – Mean annual air temperature, PAVG [mm] – Mean annual precipitation total, MCIV−IX [mm] –

Moisture certainty from April to September, DPIV−IX [%] – Probability of dry periods from April to September

Main Soil Unit (x.**XX.**x.x)

Second and third numbers distinguish one of 78 main soil units (HPJ) defined in EPEU system. These units are divided into 13 soil groups which are characteristic with same properties. In future new soils would be classified and added into HPJ classification. These soils developed under human influence (Anthrosol and Technosols) or developed subjected to water erosion (Fluvisols) (Vopratil, 2011). Main soil unit and soil-forming substrates are described in annexes no.1 and 2.

Exposition and slope (x.xx.**X.**x)

Fourth number represents a combination exposition and slope factors. These two conditions are defined by many influences. Slope is possibly affected byland cultivation and used technology, which increase erosion on steep slopes. Soil porosity and water retention capacity are affected as well.

Exposition is also highly important aspect in BPEJ classification. It affects vegetation in means of temperature patterns, light and precipitation conditions. In figure no. there are described slope and exposition characteristics (Vopratil, 2011).

Figure no. :Slope and exposition code

Code	Slope			Exposition	
	Degrees	**Characteristic**	**Categories**	**Characteristic**	**Categories**
0	0 - 3	Plane	0 -1	without distinciton	0
1	3 - 7	Gentle slope	2	without distinciton	0
2	3 - 7	Gentle slope	2	South (SW - SE)	1
3	3 - 7	Gentle slope	2	North (NW - NE)	3
4	7 - 12	Moderate slope	3	South (SW - SE)	1
5	7 - 12	Moderate slope	3	North (NW - NE)	3
6	12 - 17	Significant slope	4	South (SW - SE)	1
7	12 - 17	Significant slope	4	North (NW - NE)	3
8	17 - 25	Steep slope	5 - 6	South (SW - SE)	1
9	17 - 25	Steep slope	5 - 6	North (NW - NE)	3

Soil depth and stoniness (x.xx.x.**X)**

These two last characteristics of terrain presents a fifth number of BPEJ code and and significantly affect farming and its function. Vopratil, (2010) describes these properties of soil as:

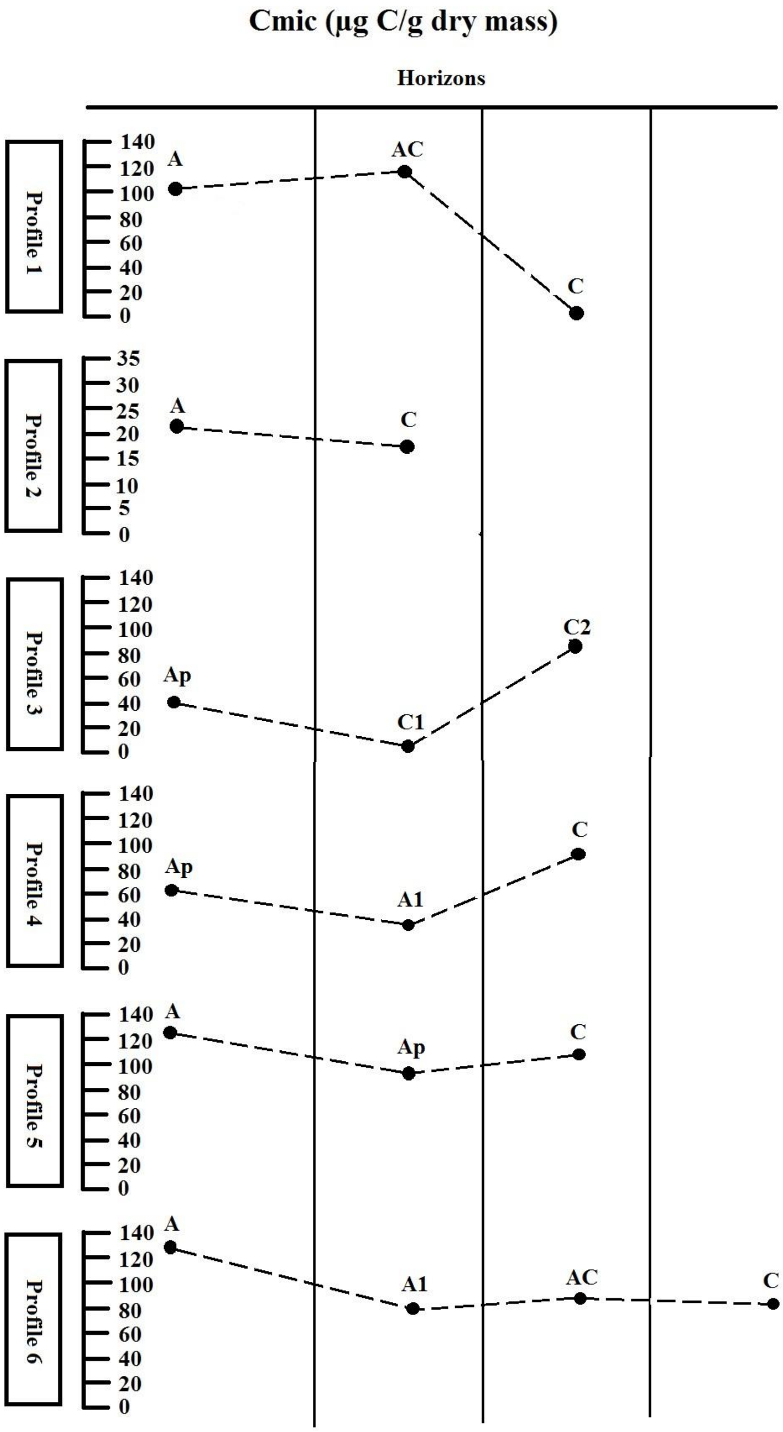
1. Stoniness indicates amount of soil particles in soil and it's determined in soil profile or on soil sample. Stoniness is divided to granulometric fractions of gravel (0,4 – 3 cm), stones (3 – 30 cm) and boulders (> 30 cm). Character depends on rock and its weathering resistance.

2. Soil depth is defined by the genetic-depth of soil profile which is restricted by solid rock, its debris or ground water level.

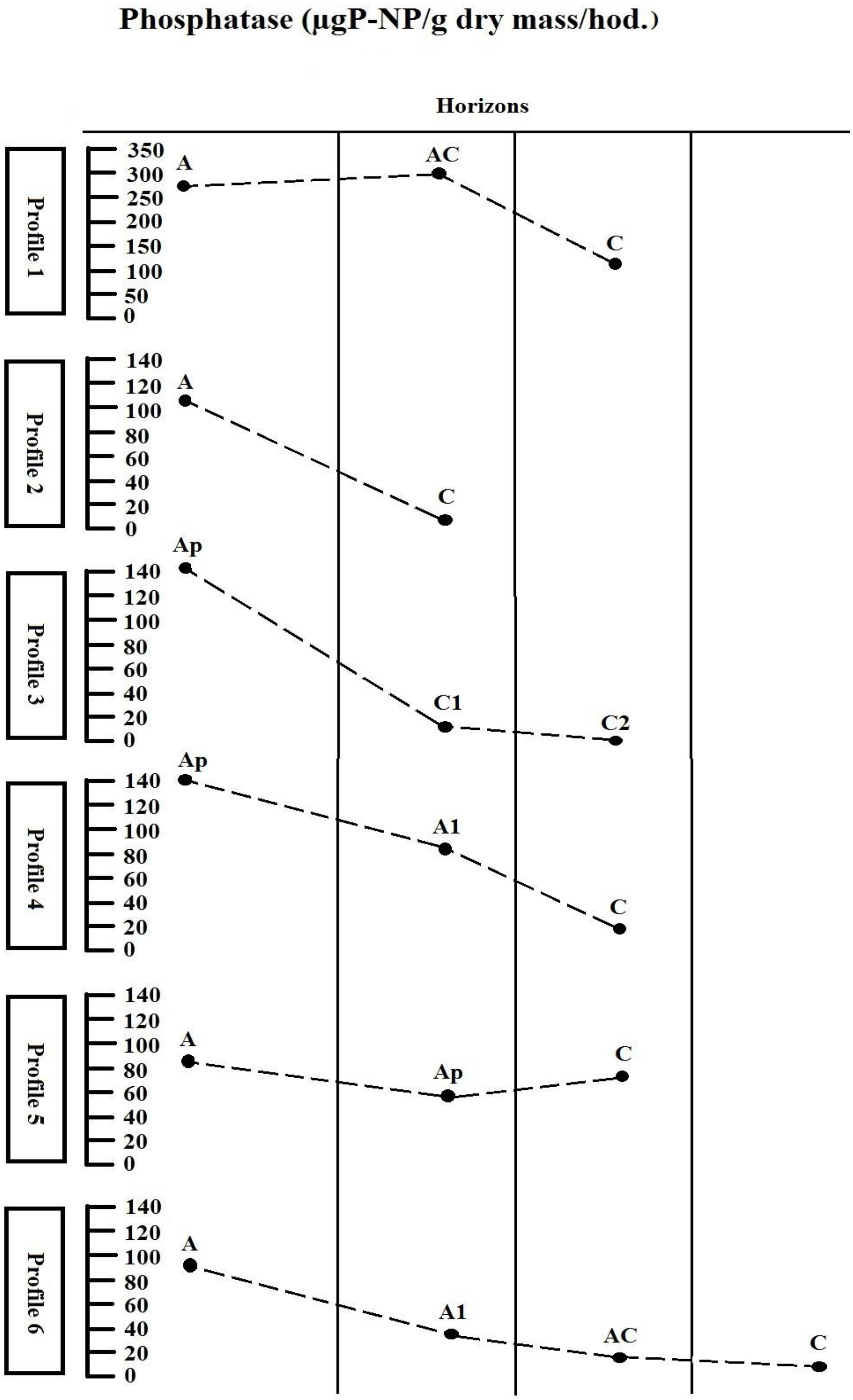
Figure no.2, **Stoniness and soil depth**

Code	**Stoniness**		**Soil depth**	
	Soil characteristics	**Category**	**Characteristics**	**Category**
0	Soil without rock	0	Deep	0
1	Soil without rock or weak occurence	0 - 1	Deep or moderate deep	0 - 1
2	Soil with weak occurence of rock	1	Deep	0
3	Soil with moderate occurence of rock	2	Deep	0
4	Soil with moderate occurence of rock	2	Deep or moderate deep	0 - 1
5	Soil with weak occurence of rock	1	shallow	2
6	Soil with moderate occurence of rock	2	shallow	2
7	Soil without rock to weak occurence of rock	0 - 1	Deep or moderate deep	0 - 1
8	Soil with moderate to large occurence of rock	2 - 3	Deep or shallow	0 - 2
9	Soil without rock to large occurence of rock	0 - 3	Deep or shallow	0 - 2

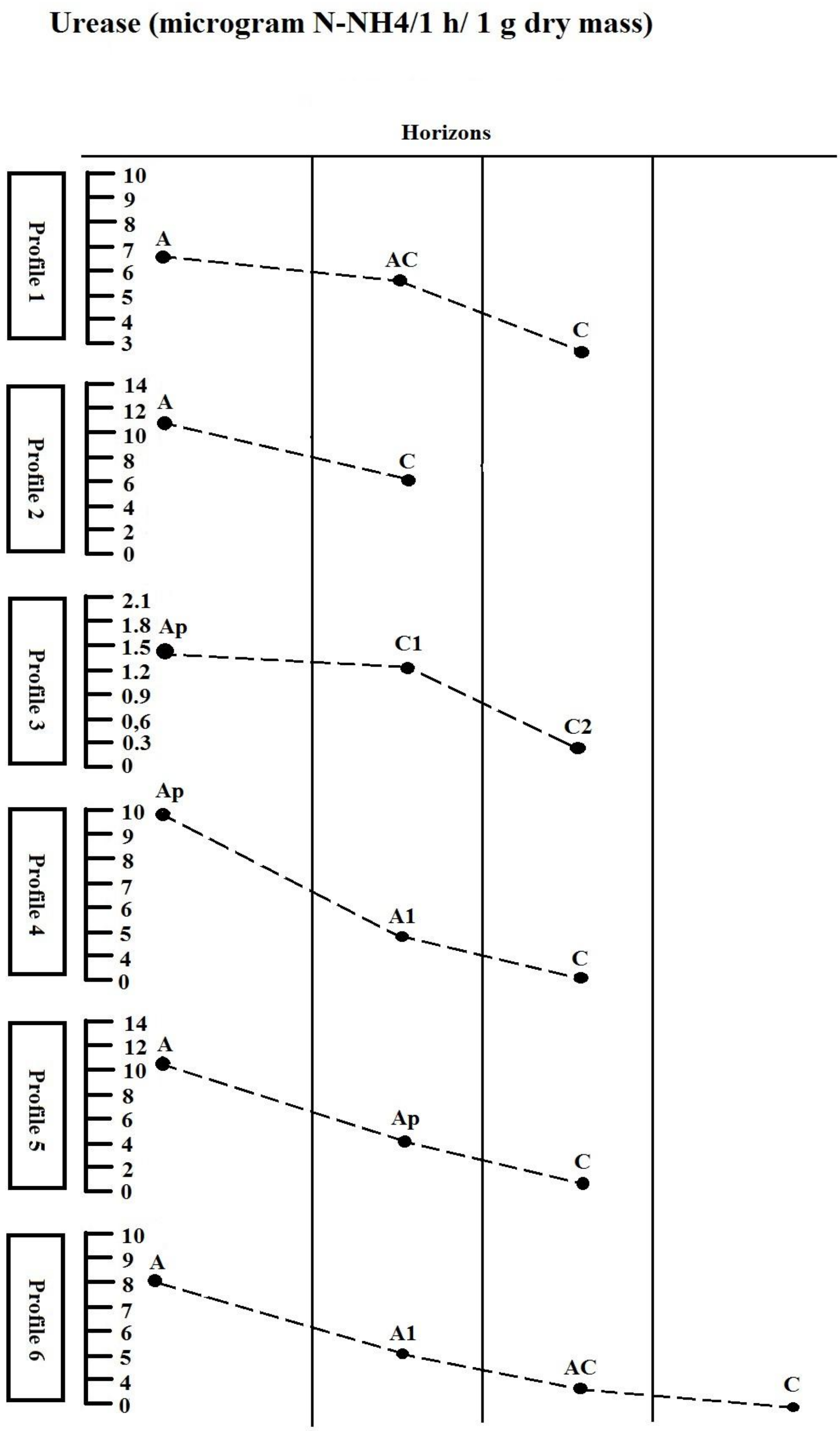
11.2. C_{mic} Distribution



11.3. Phosphatise distribution



11.4. Urease distribution



11.5. Data – physical cylinders

Profile number	Horizonts	Weight cylinder + soil	Weight dry cylinder + soil	Empty cylinder	Spec. gravity of soil (ρs)
1	A	299,19 296,83 297,41	279,17 277,27 278,96	122,13 119,02 118,83	5,72
	AC	289 286,55 299,38	256,43 254,4 267,15	109,58 102,11 117,81	2,55
	C	295,65 304,42 263,7	263,79 285,82 245,01	109,15 130,01 93,99	4,24
2	A	323,44 286,52 299,94	291,13 264,12 264,23	143,63 100,02 96,42	3,47
	C	296,06 277,74 335,7	274,85 242,17 301,26	124,56 80,06 161,49	2,24
3	Ap	293,55 278,19 294,79	287,38 269,9 287,04	129,09 144,65 118,79	2,76
	C1	321,52 307,61 285,08	315,94 301,43 279,08	151,27 127,71 109,81	2,92
	C2	305,22 278,84 287,75	299,17 273,68 282,58	128,23 107,14 116,47	2,68

Profile number	Horizonts	Weight cylinder + soil	Weight dry cylinder + soil	Empty cylinder	Spec. gravity of soil (ρs)
4	Ap	300,68	279,83	109,15	2,16
		278,04	260,66	103,47	
		298,67	278,74	112,85	
	A1	308,7	280,38	110,35	2,85
		311,44	285,62	118,42	
		308,93	281,53	116,84	
	C	328,5	309,77	134,4	3,19
		332,16	311,38	137,83	
		337	313,16	128,28	
5	A	303,64	288,09	145,75	2,68
		316,46	299,65	151,87	
		288,79	272,95	132,95	
	Ap	346,96	327,78	158,17	2,41
		339,02	319,94	151,36	
		322,08	304,38	146,86	
	C	330	315,04	147,75	2,4
		337,03	321,87	155,03	
		311,89	296,84	137,23	
6	A	279,42	272,75	135,21	2,53
		293,32	285,2	146,46	
		299,5	291,78	159,7	
	A1	313,26	305,28	160,15	2,61
		311,92	305,37	160,01	
		286,43	280,06	139,92	
	AC	309,47	305,75	154,79	2,69
		306,73	302,75	149,17	
		299,42	296,2	146,14	
	C	294,21	291,24	143,3	2,89
		306,98	304,11	154,29	
		301	297,56	152,87	

11.6. Data – phosphatase activity

Profiles	Horizons		
1	A	o	0,532
		o	0,526
		k	0,206
	AC	o	0,61
		o	0,537
		k	0,233
	C	o	0,182
		o	0,277
		k	0,096
2	A	o	0,167
		o	0,161
		k	0,038
	C	o	0,051
		o	0,058
		k	0,047
3	Ap	o	0,197
		o	0,233
		k	0,031
	C1	o	0,035
		o	0,033
		k	0,018
	C2	o	0,021
		o	0,023
		k	0,016

Explanation: **o** investigated sample, **k** controled sample

Profiles	Horizons		
4	Ap	o	0,206
		o	0,181
		k	0,023
	A1	o	0,147
		o	0,136
		k	0,041
	C	o	0,147
		o	0,125
		k	0,113
5	A	o	0,116
		o	0,147
		k	0,028
	Ap	o	0,097
		o	0,099
		k	0,026
	C	o	0,126
		o	0,123
		k	0,03
6	A	o	0,142
		o	0,158
		k	0,041
	A1	o	0,091
		o	0,096
		k	0,042
	AC	o	0,052
		o	0,051
		k	0,028
	C	o	0,038
		o	0,045
		k	0,029

Explanation: **o** investigated sample, **k** controled sample

11.7. Data – C_{mic}

Profile	Horizon	F	F	F	NF	NF	NF
1	A	1,664	1,373	1,164	1,707	1,805	1,835
	AC	1,089	1,229	1,385	1,498	1,59	1,684
	C	1,606	1,57	1,679	1,477	1,339	1,419
2	A	1,688	1,42	1,727	1,679	1,757	1,644
	C	1,803	1,795	1,742	1,748	1,888	1,858
3	Ap	1,636	1,596	1,701	1,817	1,748	1,777
	C1	1,806	1,828	1,809	1,833	1,822	1,84
	C2	1,09	1,083	0,941	1,103	1,107	1,095
4	Ap	1,397	1,473	1,456	1,65	1,675	1,656
	A1	1,687	1,693	1,614	1,747	1,815	1,775
	C	1,018	1,083	1,098	1,106	1,104	1,124
5	A	0,749	0,773	0,774	0,837	0,815	0,53
	Ap	0,914	0,911	0,918	0,884	0,837	0,841
	C	0,938	0,898	0,863	0,901	0,884	0,96
6	A	0,741	0,695	0,681	0,797	0,781	0,789
	A1	0,894	0,882	0,826	0,563	0,615	0,71
	AC	0,902	0,926	0,954	0,857	0,84	0,868
	C	0,999	1,01	0,983	1,046	0,958	0,948

Zero: 0.188

Explanations: **F** (Fumigated samples), **NF** (Not fumigated samples)

11.8. Datas – Ureases

1	A	o	0,12
		o	0,093
		o	0,099
		k	0,054
	AC	o	0,096
		o	0,088
		o	0,086
		k	0,052
	C	o	0,053
		o	0,062
		o	0,054
		k	0,038
2	A	o	0,093
		o	0,106
		o	0,108
		k	0,03
	C	o	0,044
		o	0,039
		o	0,035
		k	0
3	Ap	o	0,039
		o	0,049
		o	0,048
		k	0,035
	C1	o	0,035
		o	0,034
		o	0,029
		k	0,026
	C2	o	0,029
		o	0,029
		o	0,028
		k	0,026

Explanation: **o** investigated sample, **k** controled sample

4	Ap	o	0,14
		o	0,147
		o	0,106
		k	0,058
	A1	o	0,07
		o	0,06
		o	0,07
		k	0,033
	C	o	0,033
		o	0,033
		o	0,033
		k	0,029
5	A	o	0,153
		o	0,155
		o	0,159
		k	0,078
	Ap	o	0,096
		o	0,087
		o	0,083
		k	0,057
	C	o	0,088
		o	0,077
		o	0,08
		k	0,076
6	A	o	0,18
		o	0,127
		o	0,122
		k	0,082
	A1	o	0,099
		o	0,098
		o	0,09
		k	0,058
	AC	o	0,085
		o	0,097
		o	0,092
		k	0,065
	C	o	0,076
		o	0,082
		o	0,097
		k	0,073

Explanation: **o** investigated sample, **k** controled sample

11.9. Poznań climate condition (1995 – 2015)

Poznan climate conditions (1995 - 2015)									
Year	**T**	**TM**	**Tm**	**PP**	**V**	**RA**	**SN**	**TS**	**FG**
1995	8,8	13,2	3,9	497,39	11,2	167	63	23	44
1996	7,1	11,1	2,7	542,32	10,2	149	64	21	57
1997	8,5	12,8	3,8	631,2	10,8	172	45	19	49
1998	9	13,4	4,7	570,75	11,7	175	42	18	27
1999	9,5	14	4,7	673,57	11	179	57	32	47
2000	10	14,6	5,4		13,1	200	37	24	67
2001	8,9	13,2	4,4		13,4	202	58	15	56
2002						178	43	18	40
2003	9	14	3,6	406,14	13,1	161	44	17	48
2004	9	13,6	4,3	493,74	14,1	197	65	21	49
2005									
2006	9,7	14,2	4,8	441,7	12,3	163	50	17	43
2007	10,1	14,5	5,5	574,02	13,9	198	36	24	34
2008	10,2	14,4	5,6	501,08	13,4	191	30	17	41
2009	9,3	13,6	4,7	585,2	12,5	180	42	28	64
2010	8	12,1	3,4	723,36	12,8	168	85	21	57
2011	10	14,4	5,1	484,31	12,9	158	29	26	45
2012	9,4	13,7	5	678,43	12,6	195	46	39	61
2013	9,3	13,3	5	597,61	12,5	183	68	23	41
2014	10,7	15,1	6,2	567,63	13	204	18	28	48
2015	10,7	15,4	5,6	424,15	13,8	193	32	24	40
Total	**8,86**	**13,03**	**4,42**	**469,63**	**11,92**	**180,7**	**47,7**	**22,8**	**48**

Explanations:

T	Average annual temperature
TM	Annual average maximum temperature
Tm	Average annual minimum temperature
PP	Rain or snow precipitation total annual
V	Annual average wind speed
RA	Number of days with rain
SN	Number of days with snow
TS	Number of days with storm
FG	Number of foggy days