SOIL PHYSICO-CHEMICAL PROPERTIES

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INTRODUCTION

why do we need to study physico-chemical properties of soil?

The soil productivity has been the base of development and survival of civilizations by providing food and other essential goods for humans (Hillel 2009). It is important to choose the proper land use as the global issues of 21th century including food security, demands of energy and water, climate change and biodiversity are connected with the sustainable use of soils (Lal 2008, 2009; Jones et al. 2009; Lichtfouse et al. 2009). It is concerned that the global cereal yield trends are not increasing fast enough (Cassmann et al. 2003) while it should not be forgotten that satisfying the global agricultural demands cannot outweigh the soil capacity. Studying soil and its properties helps to prevent problems like erosion, degradation and pollution, helps to determine soil quality and also gives references for further studies.

There have been several studies about the same topic as this project. For example, Lal (2004) wrote a review about soil Carbon sequestration to mitigate the climate change, Suuster et al. (2012) were modelling soil organic Carbon concentration of mineral soils in arable land by using legacy soil data. Mueller et al. (2010) wrote a review about evaluation of soils productivity functions.

The aims of this mini-project are:

- to underline relations between physico-chemical properties, land use and soil quality;
- to determine correlation between land use and Carbon stock in soils.

We collected soil samples from different landscapes and divided these into 5 groups: peatland, wetland, forest, grassland and cropland. According to the division and the relations with Carbon stock the project has 2 hypotheses:

- the soil Carbon stock will be higher in the forest and wetland soils, also in the peatland and the smallest Carbon stock will be in the cropfield;
- the peatland should be the most acidic soils.

MATERIALS AND METHODS

Soil sampling method

Equipment and tools:

1. Shovel
2. Bags
3. Remark pen
4. Notepad

Generally we are taking soil samples from representative places, and it should be random and inside plant community what we chose, not in peripheral parts of plant community. We need to write down on bags or to notepad right depth we are taking. And we need write down another important information like sampling date, location (coordinates if available), landscape position, elevation, land use and plant community. This is necessary for conclusions from samples later.

The samples were collected from: Trebon peat soil (10-15 cm and 0-5 cm), Slavošovice pseudogley ,5-10 cm and 0-5 cm ,Trebon Organic fibric soil – drained, flooded again, 10-15 cm and 0-5 cm), Šumava soil with podzoils (0-5 cm and 0-5 cm), České Budějovice pseudogley (0-10 cm), Šumava peat soil (2x 0-5 cm and 10-15 cm), Slavošovice Pseudogley 5-10 cm and 0-5 cm), Šumava II organic fibric soil, fluvisol (0-5 cm) which is subscribe more in Table 1.

We used analysis … Finger test, Determination of pH, Soil moisture, Loss on ignition (Direct estimation of Organic Matter- LOI) and Extraction of mineral forms of N

Finger test

Equipment and tools:

1. Hands
2. Water
3. Use of guideline (ftp://ftp.fao.org/agl/agll/docs/guidel_soil_descr.pdf)

We can difference soils to groups by finger test. Finger test give us outcomes, which are practically based on properties of soil consistence when we made soil wet. Beside that we can determinate by finger test amount of clay.

For finger test we will take soil in our hands and make soil wet enough, but it must be just like wet without lack even excess of water. We can talk about two main groups at first. In situation when this soil is not possible to roll in our hands, then we talk about some type of sand with wire of about 7 mm in diameter. Here we difference just sand, unsorted sand, very coarse and coarse sand, medium, fine and very fine sand, loamy sand and sandy sand.

Another types of soil are types that are possible to roll. Here we can difference to another two groups. First is that soil breaks when we trying to form and adheres to the fingers, wire is about 3-7 mm in diameter. Another categorization we found for soil if it is more grainy or not, and sort of plasticity as well, so we can found soil belong to silt loam, silt, sandy loam, loam, silt loam or sandy clay loam. Second group of soil which are possible to roll has shiny surface after squeezing between fingers. And we can form the wire to a ring of about 2-4 cm in diameter, it is cohesive and sticky. Here we have sandy clay, clay loam, clay, silty clay loam, silty clay and heavy clay and these are depending again on various grainy or not grainy structure for to decide final category.

Determination of pH

Method: pH is defined as the negative logarithm of the aktivity of hydronium ions in a solution. pH meter was used. Rod of pH meter is inserted into moistened soil and measures the concentration of hydrogen ions.

Equipment and tools:

1. Balance
2. Glass jars
3. pH-meter

Procedure:

5 g of fresh soil weight in glass jar, add 25 ml of deionized water (H_2O) or 1 M KCl. Suspension is intensively shaken for 20 min and then measured after two hours by pH-meter.

Soil moisture

Method:

With increasing of temperature first water soil pores evaporates, then water adsorbed to mineral surfaces, followed by water between lattice layers and that which forms part of the mineral lattice itself. Water adsorbed to organic components (as well as other volatile organic substances) will also evaporate over a range of temperatures. Used temperature for dry soil was 105°C.

Equipment and tools:

1. Balance
2. Cans
3. Oven
4. Desiccator

Procedure:

1. Weigh can to 0.01 g. Record can ID and weight.
2. Mix sample thoroughly.
3. Place about 10-30 g sample in can
4. Weigh and record weight (can + Moist Sample).
5. Place can in oven
6. After 24 hours, remove cans from oven. Cover with lids and put in desiccator to cool (about 20-30 minutes) . Weigh and record weights (Tare + Dry Sample). You may take it out of the oven before 24 hours, but you should check for constant weight (i.e., cool, weigh, put back in oven for an hour, cool, weight again)
7. Calculate eater concentration, using appropriate units

Loss on ignition (Direct estimation of Organic Matter) - LOI

Method: Direct estimation of organic matter by loss on ignition is practically comparing the weight of a sample before and after the soil has been ignited. Ignition is strongly heating in specific temperature. Before ignition the sample contains organic matter, but after ignition remains the mineral portion of the soil. The difference in weight before and after ignition represents the amount of organic matter presented in sample.

Equipment and tools:

1. Analytic balance
2. Electric oven (muffel oven)
3. Ceramic crucible
4. Desiccator

Procedure:

1. Dry crusibles at 105°C.
2. Cool in desiccator for 30 min
3. Weigh crucibles
4. Add sample, about one third of crucible.
5. Weigh crucible with sample
6. Place crucible into the muffel oven, leave there for 4 hours at 550 °C
7. Using the special tool to take out the crucibles, place them in a desiccator to fully cool.
8. Weigh crusibles

Extraction of mineral forms of N

Method: Nitrogen is evaluated by the amounts of NH_4^+ -N and NO_3^- -N that are extracted with KCl or H_2O solution from soils.

Equipment and tools:

1. Balance
2. Glass jars
3. Shaker
4. Centrifugation tube
5. Filtering apparatus - vacuum pump
6. Glass fiber filters (0,45 µm)
7. Extractant – deionized water

Procedure:

1.) Extraction of NH_4 and NO_3
- 10 f of fresh sieved soil weigh into 100 ml glass jars
- add 40 ml of H_20
- shake the suspension on the shaker for 1h
- after shaking pout the solution into centrifugation tube, centrifuge 10 min,
- filtration through the glass fiber filter

2.) Analysis
- Filtrates are analyzed for content of N-NO_3 a N-NH_4 next day, stored at cooling room at 4°C
- Concentrations analyzed by FIA (Flow Injection Analyzer)

3.) Calculation
- Content of NO_3^- and NH_4^+ will be recalculated per gram of dry soil (mg N-NO_3^-.g^{-1}, mg N-NH_4^+.g^{-1})

$$\frac{c\ N\text{-}NO_3 * V}{1000 * m * \text{dry weight}} \quad [\text{mg N-}NO_3.g^{-1}\text{ dry soil }]$$

c N-NO_3 …….. concentration of NO_3^-/NH_4^+ in the extract from soil sample in mg N-NO_3^- . l^{-1}
V ………………. Volume of extractant (H_20) you added to the soil sample (ml)
m ……………… weight of fresh soil (g)

RESULTS

The results of the study about soil physico-chemical soil properties are shown below (table 1 and 2). Those tables are sorted in two main groups to separate physical and geological contents from chemical ones.

Table 1: Taken samples and their geological properties, ordered in five main-groups that are 'peatland', 'forest', 'wetland', 'agricultural land' and 'grassland'

No.	Site	Depth of sample (cm)	Soil map	Land use	Plant community	Decom-position/texture
Peatland						
7	Sumava I	0 – 5	peat soil	peatland	mosses	strong decomposed
12	Sumava I	10 – 15	peat soil	peatland	mosses	strong decomposed
forest						
8	Sumava III	0 – 5	soils with podzol	forest (beech)	beech mainly	strong decomposed
9	Sumava IV	0 – 5	soils with podzol	forest (spruce)	spruce mainly	moderate decomposed
wetland						
1	Trebon I	10 – 15	peat soil	wetland	grasses	low decomposed
2	Trebon I	0 – 5	peat soil	wetland	grasses	low decomposed
5	Trebon II	10 – 15	organic fibric soil	wetland	grasses	low decomposed
6	Trebon II	0 – 5	organic fibric soil	wetland	grasses	low decomposed
15	Sumava II	0 – 5	organic fibric soil	wetland	grasses	low decomposed
agricultural land						
10	Ceske Budejovice	0 – 10	pseudogley	agricultural land	maize	loamy sand
grassland						
3	Slavosovice I	5 – 10	pseudogley	grassland	grasses	silt loam
4	Slavosovice I	0 – 5	pseudogley	grassland	grasses	clay loam
13	Slavosovice II	5 – 10	pseudogley	grassland	grasses	clay loam
14	Slavosovice II	0 – 5	pseudogley	grassland	grasses	clay loam

Soils in peatland and forests are highly decomposed according to the test taken about the degree of decomposition and humification.

To analyze the texture of agricultural land and grassland another test, the so called 'finger test' has been used. Those soils had a loamy texture whereat the agricultural land had texture between sand and loam but the grasslands had a texture which was between loam and clay.

Table 2: Taken samples and their chemical properties (pH, Moisture, Loss on Ignition, Nitrate, Ammonium and soil organic carbon stock), ordered in five main-groups that are 'peatland', 'forest', 'wetland', 'agricultural land' and 'grassland'

No.	**pH (H_2O)**	**pH (KCl)**	**Moisture (%)**	**LOI (%)**	**NO_3^- (mg/g)**	**NH_4^+ (mg/g)**	**SOC stock (kg/m^2)**
peatland							
7	3.19	2.57	63	89.3	0.332	0.146	20.6
12	3.32	2.70	77	96.7	0.181	0.091	11.7
forest							
8	3.77	3.06	61	73.2	1.17	2.120	35.6
9	3.31	3.06	31	25.9	0.0821	0.135	38.2
wetland							
1	5.12	4.53	66	46.2	0.226	0.130	45.7
2	5.47	4.82	76	89.8	0.174	0.095	20.1
5	5.16	4.83	10	10	0.405	0.050	20.2
6	5.14	4.42	19	25.6	0.448	0.056	38
15	5.56	4.96	70	9.4	0.0827	0.086	19.3
agricultural land							
10	5.72	5.05	5	2.9	1.21	0.073	7
grassland							
3	6.25	5.53	13	9.5	0.68	0.339	19.5
4	5.92	5.24	14	10.9	0.274	0.070	21.7
13	5.40	5.23	12	9	0.665	0.145	18.7
14	5.98	5.44	13	10.7	0.451	0.113	21.4

The soils pH-value of each of the different soil types is rather acidic (table 2) which is common in soils in Czech Republic. The most acidic soils were being found in peatland and forests, spruce forest as well as beech forest. Those pH-values were around 2 to 3.5. Soils from wetlands, grasslands and agricultural land were still acidic but had a tendency to neutral pH-value. Those pH-values were around 4 to 6.

First of all it needs to be mentioned that there are two different sources of nitrogen in soils. First there is nitrate (NO_3^-) and then there is ammonium (NH_4^+). Low nitrogen contents were being found in peatland, spruce forest, wetland and grassland soils. In peatland and wetland soils the nitrogen content based on ammonium is twice as high as nitrogen content based on nitrate.

In grassland soils the nitrogen content based on ammonium is three times as much as the nitrogen content based on nitrate. The nitrogen content in spruce forest is around 0.6 mg of nitrogen per gram of soil. Compared to the spruce forest, beech forest contains much more nitrogen with around 16 mg of nitrogen per gram of soil. Agricultural soils contain a medium nitrogen content compared to the other soil types that have been observed in this study. Withal the nitrogen content based on ammonium is ten times as high as the nitrogen content based on nitrate.

With moisture of 70% peatland soils contain the most water out of the observed soil types. Forest and wetland soils however contain only around 50% of water which makes them moderately moist. Soils with the lowest moisture and therefore lowest water content are agricultural soils with 5% of water content and grasslands with 12% of water content.

In cases of organic matter content peatland and beech forest soils contain a high amount of it. For peatland the organic matter content are 93% and for beech forest there are 73%. Spruce forest and wetland soils contain only medium amount of organic matter with 25 to 36%. But agricultural and grassland soils contain the least amount of organic matter. The organic matter content of grassland soils is 10% and for agricultural soils it is only 3%, which is quite good for agricultural used land, but not as high as in unused grassland.
The different carbon contents in the different soil types were measured as well. Peatland and forest soils contain the most carbon whereas wetlands and grasslands contain only medium amounts of carbon with around 20 to 30 kg/m^2. But the least amount of carbon is in agricultural land with only 7 kg/m^2.

DISCUSSION

Peatland and forest soils are highly decomposed, because there is much organic matter to be decomposed like branches, needles, leaves and dead animals. The decomposition process can be undisturbed in both soil types because of their special nature protection. Soils in agricultural land have a sandy or loamy texture because it contains a lot of fertilizers, not much carbon and only a small range of different nutrients. Grassland soils have a clay-like texture since they can store water in between their soil particles which makes the soils moist. Another possible explanation can be that there is a high decomposition rate of organic matter in grassland soils.

The different plant communities on different soil types depends on the adaptations of the plant growing there, on pH-value, on the geology, on the water content and on the soil texture.

Concerning pH-value first of all it needs to be said, that all soils in Czech Republic are acidic in some way. This is because of the H^+ ions dissolved in the soils. The decomposition process of organic matter takes place in many different stages. Two of the most important stages of decomposition for this study are shown in the following:

Organic matter → nitrate (NO_3^-) → ammonium (NH_4^+)

The most acidic soils with a low pH-value were being found in peatland and forest soils which is based on the long decomposition rate which leads to ammonium. Because of the high content of NH4+ in peatland and forest soils there also is a high amount of H^+ ions in the soil which makes it acidic. The other three soil types were still acidic but had a tendency to a neutral pH-value since farmers use this kind of soil types to grow plants for feeding or selling and those farmers try to keep the soil as neutral as possible because there would not grow any plants a very acidic soils.

The two different pH-values, once measured with the soil samples dissolved in water and once dissolved in potassium chloride, can be explained by the following (figure 1).

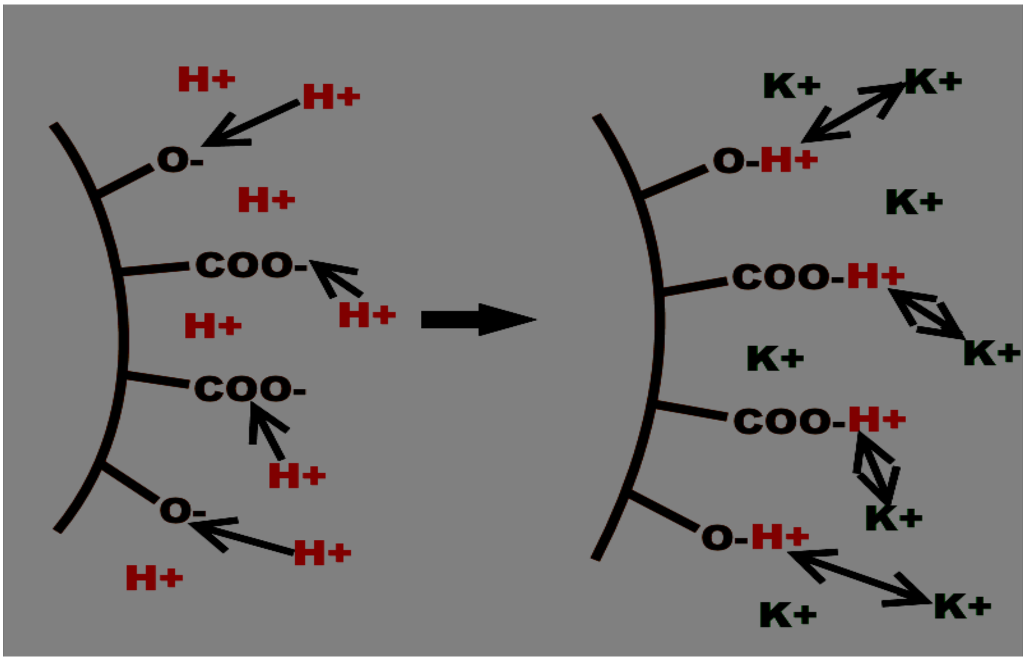

Figure 1: Soil colloids have a negative charge (like O- and COO-), dissolved H+ ions can bind to that colloids which is the case when measuring the pH-value with water, when measuring the pH with KCl there are K+ ions in the solution and they can replace the H+ ions binding to the soil colloids and therefore there are more H+ ions in the measured solution which results in a lower pH-value when measured with KCl

Nitrogen contents in different soil types were being measured once through nitrate-content and once through ammonium-content. This is important because of the different stages of decomposition taken place in every single soil type. Some soils have a low decomposition rate and only contain nitrate whereas other soils have a high decomposition rate and also do contain ammonium. Low nitrogen contents were being found in peatland, beech forest, wetland and grassland soils because there are many plants that use up all the nutrients present in the soil. The difference between the amount of nitrogen in spruce and beech forest soils is down to the fact that in spruce forest soils there is more organic matter because lignin and phenolic acids stop the decomposition. The nitrogen molecules are being stored in the litter and therefore can not be leached out. Agricultural soils in contrast contain much more nitrogen although many plants grow there that use the nutrients. This is because the farmers use fertilizers which have a high amount of nitrogen in them. Despite peatland, wetland and grassland soils contain only few amount of nitrogen there is a difference in whether the source of nitrogen is nitrate or ammonium. In those soils the nitrogen based on ammonium is two or three times as high as the nitrogen based on nitrate since there are long decomposition processes in those soils which lead up to ammonium (process shown above). Differences between nitrate and ammonium as nitrogen source is even more extreme. The amount of nitrogen based on ammonium is ten times as high as the amount of nitrogen based on nitrate

because to fertilizers used contain a high amount of ammonium.
Peatland soils can store a lot of water in between their soil particles and because the soils is very dense the water can not go out by evaporation or transpiration. Forest and wetland soils are constituted only of 50 % water since all the plants growing there need the water to survive and so they use it. The space between soil particles in forest and wetlands are bigger so the water is easier to reach and it can be evaporated. The soils with the lowest moisture are agricultural with only around 5 % of water content and grassland soils with only 12 % of water content. A reason for that might be the agricultural use of those areas which does not contain irrigation. The only water in the soil comes form precipitation which was very rare in the weeks before the samples were taken so the soils are dried out.

The highest amount of organic matter and carbon were being found in peatland soils with around 93 % of organic matter and in beech forest with around 73 % of organic matter. Peatland soils almost only consist of carbon and organic matter which can be seen in the black colour of the soil samples. In protected peatsoils and forests there is no removal of the organic matter so the decomposition process can take place over years without disturbances. Spruce forest and wetland soils contain only medium amount of organic matter because phenolic acids and lignin are very hard to be decomposed, but there is not the one solution because the samples were taken from only zero to ten cm in depth which does not represent the entire A-horizon of the soil.
Least amounts of organic matter and carbon were being found in agricultural and grassland soils because of the frequent use of these soils and its vegetation. Each tillage and each mowing where the mowed material is removed from the soil reduces the organic matter and carbon content in the soil.

Limitations

During the project we had several shortcomings due to different reasons. Firstly, there was too little time for the project to have comprehensive results. Secondly as a consequence of time deficiency and too few samples we cannot really generalize. E.g. we had only two samples from the forest and only one sample from the cropfield. Thirdly the results in SOC pool equation were not specific because we used a coefficient as we did not have the measured bulk density. Also there was a lack of background information (geology, history of land use, fertilization etc) and the samples were taken only from the upper level of the soil horizon.

CONCLUSION

Prediction was made on 15 soil samples collected from different sites in Czech Republic to check for their SOC concentration, soil functioning, fertility, physical and chemical properties. Definitely, the good standard soil properties serves as an indicators of soil quality which can be complex and also vary among forest systems.

According to the soil index models, the properties of soil such as. Organic matter content, nutrient supplying capacity, acidity, bulk density, porosity and availability of water holding capacity are most times responsible for the soil functions.

Indicator category	**Related soil function**
Biological	Biodiversity, Nutrient cycling, Filtering
Physical	Physical stability, Support, Water Relations, Habitat
Chemical	Nutrient cycling, Water Relations, Buffering

From our mini-project, the physical properties of the soil samples we used showed good relationships with the amount of soil organic matter and that is the normal standardized soil functioning in its capacity of biomass produce (productivity) which will be very good for human continuous usage.

REFERENCES

Cassmann KG, Dobermann A, Walters DT, Yang H (2003) Meeting cereal demand while protecting natural resources and improving environmental quality. Annual Review of Environment and Resources, 28, 315-358

Hillel D (2009) The mission of soil scince in a changing world, Journal of *Plant Nutrition and Soil Science*, **172**, 5-9

Jones A, Stolbovoy V, Rusco E, Gentile A-R, Gardi C, Marechal B, Montanarella L (2009) Climante change in Europe. 2. Impact on soil. A review, Argonomy for Sustainable Development, 29, 423-432

Lal R (2004) Soil Carbon sequestration to mitigate climate change. A review. Geoderma, 123, 1-22

Lal R (2008) Soils and sustainable agriculture. A review, Argonomy for Sustainable Development, 28, 57-64

Lal R (2009) Soils and food sufficiency. A review. Argon. Sustainable Development, 29, 113-133

Lichtfouse E, Navarrete M, Debaeke P, Souchere V, Alberola C, (2009) Argonomy for Sustainable Development, Springer, 1st edition, 645

Mueller L, Schindler U, Mirschel W, Shepherd TG, Ball BC, Helming K, Rogasik J, Eulenstein F, Wiggering H (2010) Assesing the productivity function of soils. A reviw. Argonomy for Sustainable Development, 30, 601-6014.

Suuster E, Ritz C, Roostalu H, Kõlli R, Astover A (2012) Modelling soil organic carbon concentration of mineral soils in arable land using legacy soil data. European Journal of Soil Science. 63, 351-359