SOILS 206 LAB
FINAL PROJECT

STUDY SITE SOIL PROPERTIES
&
MANAGEMENT PLAN

A Proposal To:
University of Idaho

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PART 1: DATA COMPILIATION OF SOIL SITE

1. SOIL SITE CHARACTERIZATION, SOIL ORDER, AND SOIL SERIES

Introduction

Located near the south entrance to the UI arboretum, our 17-acre field site looks like much of the rest of the Palouse: rolling hills covered with wheat. However, only looking at the surface of a soil only gives us a limited understanding of various soil properties. To begin, a site description is done, which documents several important features of the study area, such as aspect, slope, surrounding flora and fauna, climate, average annual precipitation, past/current use of the area and any other characteristics worth noting which could potentially affect a variety of properties affected with the soil, such as drainage, exposure to solar insolation (or shade), risk of runoff and erosion. In addition, a soil survey is completed. According to the Natural Resource Conservation Service (NRCS), a soil survey or characterization describes the characteristics of the soils in a given area, classifies the soil according to a standard system of classification, plots the boundaries of the soil on a map, and makes predictions about the behavior of the soil. A characterization of this soil site was done in order to determine the possible uses of the soil as well as how the response of management may affect the soil. Most importantly, the information collected initially through a soil site characterization is key to land-use plans and how these activities may affect the surrounding environment. For this section, we will describe the our soil site characterization (as determined via use of Web Soil Survey) as well as an overview of the parent material and geologic history of this area.

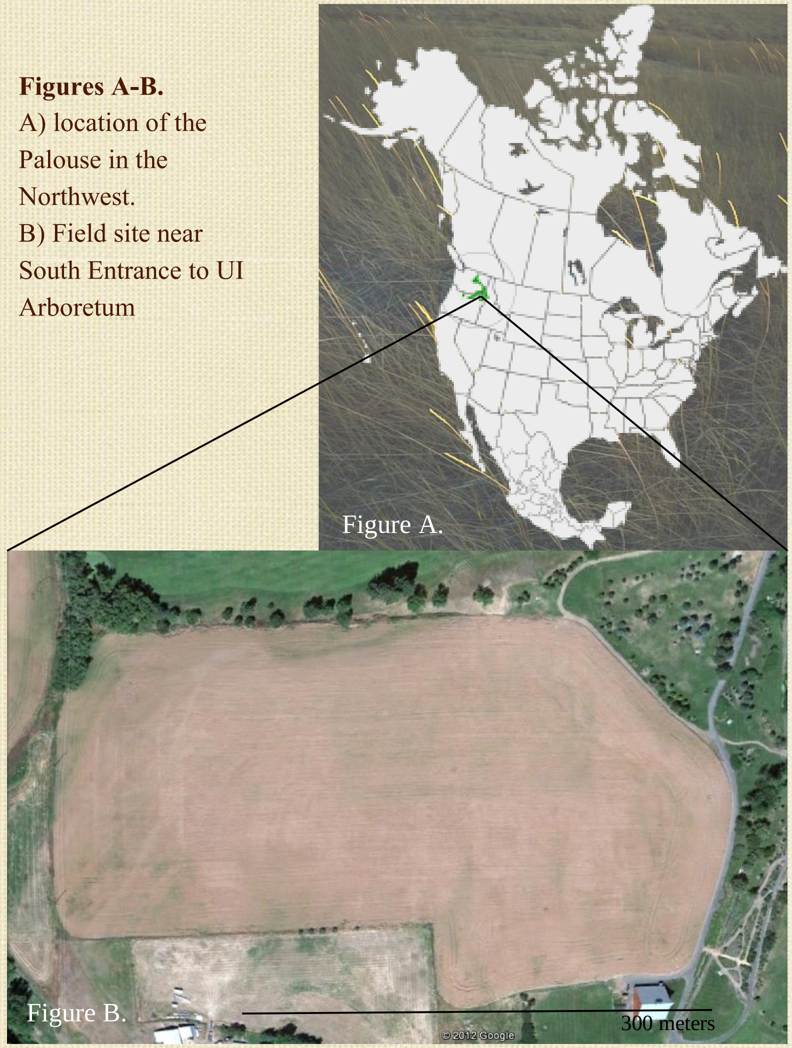
Methods

In order to determine various characteristics of the soil site, the NRCS' Web Soil Survey was utilized.

1. The Area of Interest (AOI) tab was selected to define our area of interest (i.e. our field site).
2. Various parameters were observed, such as size of the AOI, soil map units included in the AOI, the map unit symbol and map unit name of the soil pit (soil pit #5) that we excavated, among other characteristics.

In terms of methods utilized to understand the parent material and geologic history of our field site and the Palouse region at large, we observed and learned about these characteristics via a field trip through the Palouse.

Figures A-B.
A) location of the Palouse in the Northwest.
B) Field site near South Entrance to UI Arboretum



Results

Via the Web Soil Survey, we were able to determine that Latahco-Thatuna silt loams with a 0-5% slope encompassed the soil composition of our particular soil pit (#5) in our soil site. In addition, the map unit composition of our soil pit was made up of Latahco and similar soils (55%), Thatuna and similar soils (30%) and minor components (5%).

Discussion

According to the USDA-NRCS Soil Survey Division, Latahco-Thatuna (soil series) silt loams (part of the Mollisol order) are very deep soils that are commonly found along low terraces, bottom lands, and drainageways by loess hills and dissected plains. These soils are usually found at elevations between 2,500 feet to 2,800 feet with an

SOIL SITE CHARACTERIZATION CONTINUED

Discussion continued

average annual precipitation of 20 inches. Average annual air temperatures range from 43-47 degrees Fahrenheit and the average frost-free period is 120 to 135 days. Although issues of drainage and permeability will be addressed later, it is worth noting that these soils are generally used for cropland in this area (specifically wheat, barley, hay, pasture, and grass seed). Because of these characteristics, the land is often favorable and used for agricultural activities.

The geologic history of the Palouse is quite interesting. The basement rocks in the region, the oldest parent material on the Palouse. These basement rocks are mainly composed of granite and date from the Precambrian era. Although much of this granite is covered with meters of loess, some of this granite is still visible among high “steptoes” such as Moscow Mountain and Paradise ridge (see figure C.). Approximately 6-17 million years ago, a series of lava flows (Columbia River Basalts) flowed through and around this area and covered lower-lying areas. Fractures and cracks allowed movement as well as storage of water; nowadays, we take advantage of this characteristic of basalt through use of the Grande Rhone and Wanapum aquifers. Most recently, about 1-2 million years ago, vast amounts of loess were transported and deposited over the Columbia basalt layer. Interestingly enough, this loess layer covers nearly 10,000 km^2 and can reach up to 75 meters in depth in some areas. This loess is exactly what makes the Palouse such a prized region.

Over time, via loess, a soil-loamy textured soil developed that has moderate soil water holding capacity (but also high erosion susceptibility) which is absolutely essential to dryland farming in this area (no use of irrigation). However, as mentioned, this silt-loamy soil is especially prone to erosion (due to the fine texture of the soil plus the non-cohesive nature of the soil particles) which is of greatest concern when considering any land use/management plan. The parent material (along with the other 4 factors of soil formation: climate, biota, time, and topography) has a huge impact on various characteristics of the soil. For example, granite tends to form soils that are coarse and sandy in texture, drain quickly, do not hold water very well are relatively infertile. In comparison, basalt tends to form soils that are finely textured, highly fertile and hold water and drain moderately well (many characteristics of which are seen in the soil site). The rolling hills (topography) of the soil site may also make it more susceptible to erosion, especially during times of high precipitation.

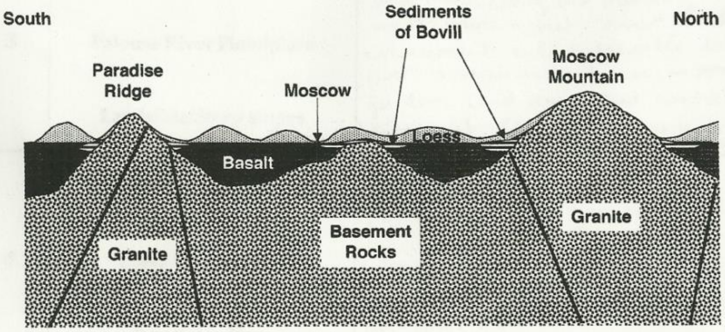


Figure C.
Cross section showing generalized geological relationships in the Moscow area.

2. SOIL PROFILE DESCRIPTION

Introduction

Seemingly basic, the soil profile is a very important tool for farmers, scientists, ecologists, soil engineers, hydrologists, land-use planners and other experts. A soil profile is the a first step to understanding the nutrient management of a soil which can further insight into soil fertility. Based upon the soil texture and structure, horizon designation, color (which may give clues to redox reactions in the soil), depth and any other distinguishing features (such as humus, mottling, permafrost, shrink-swell evidence, etc.), one is able to predict how a given soil may react under certain conditions (such as no till versus conventional farming methods). The manner by which a soil profile is found may be time and energy consuming, but it does provide a direct view of the soil for quite an extent. In addition, soil samples may be taken at various depths in order to determine mineral and nutrient content (which may be determined through various lab tests).

Methods

1. We excavated soil to create a pit that was at least 100 cm in depth.
2. Cleaning off the pit face in order to expose fresh soil, we began to describe soil horizons from the top down, using the Munsell color chart to describe soil color, determining soil texture via the “feel” method, feeling and breaking soil aggregates to estimate soil structure, and recording depths and boundaries between master and subordinate soil horizon designations.
3. In addition, we made notes about the topography, landform, vegetation, slope and aspect of the soil pit.

Results

SOIL PROFILE DESCRIPTION CONTINUED

Results

Refer to Figure D for a visual representation the soil profile of pit #5.

Oi 1-0 cm; brown (10YR 4/3) silt loam with some organic matter <10%; granular, fine; pieces of dried/decomposing wheat found; clear, smooth boundary.

Ap 0-30cm; brown (10YR 4/3) silt loam; prismatic texture, but breaks into granular and angular blocky structure; many cavities of earthworms observed; root growth noted near top and middle of this specific horizon; diffuse, smooth boundary; slightly compacted.

A1 30-60cm; brown (10YR 4/3) silt loam, slightly more clay content; granular, prismatic, angular blocky structure; continued observations of earthworm cavities; cooler and very slightly damp to the touch; more compact than previous horizon; diffuse, smooth boundary.

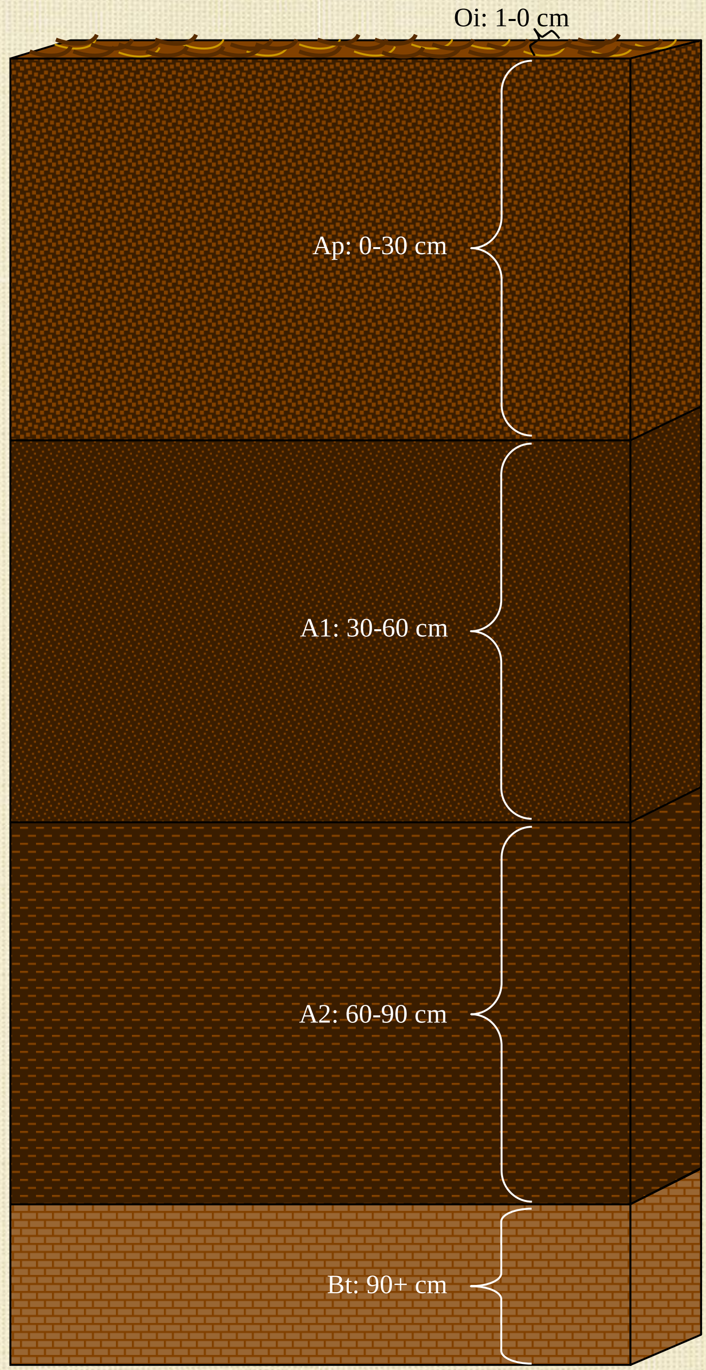
A2 60-90cm; brown (10YR 4/3) silt loam, more clay content; granular, prismatic, angular blocky structure; fewer earthworm cavities; holds moisture well; cooler, slightly more damp, and more compacted than previous horizon; clear, smooth to wavy boundary.

Bt 90+cm; light brownish grey (10YR 6/2) clay loam; granular, fine; unable to determine depth of this particular horizon since pit profile only included the first 100cm of this soil pit; much lighter in color than previous horizons (suggesting eluviation) and cooler to the touch; not as blocky as previous horizons but could be easily compacted into peds or aggregates (accumulation of clay particles).

Discussion

This pit was located at the toeslope/floodplain nearby the south entrance of the UI arboretum. This specific pit had a west aspect and slope of <5%. It was located in a cropland where an unknown *Triticum spp* was recently harvested. In addition, a small stream or creek ran close to the pit (approximately 10 meters away) where several *Salix spp.*, *Brassica spp*., and *Ribes spp*. grew. It should be noted that this stream produced a type of microclimate; it was notably cooler and wetter near the creek and this could possibly affect soil characteristics of the pit and nearby soil samples. In general, the soil seemed to be moderately well-drained although there was a lighter-colored horizon at the bottom of the pit suggesting elluviation. In addition, slower permeability may be expected for this particular soil due to increasing amounts of clay deeper along the soil profile. Because Triticum spp. is currently grown and harvested here, we could assume that this site may be able to support further cultivation. However, because of the location of this soil (near the stream) and the evidence of clay in lower horizons, there may be a chance that this soil could become flooded by the stream periodically. In addition, it may be a site of snow accumulation in the winter; both of these situations could result in slight leaching and accumulation of certain materials in lower horizons. The silt loam texture of this soil is also of concern; silt contains fine, non-cohesive particles that have moderate water retention and drainage capabilities but are also very prone to erosion.

Figure D. Soil pit #5 soil profile



3. SOIL TEXTURE: PARTICLE SIZE ANALYSIS

Introduction

Soil texture plays a crucial role in soil behavior and management by describing the relative size of soil particles in a given soil sample. Size ranges for soil particles are separated into different classes ranging from coarse fragments (>2 mm) to the fine earth fracture (<2 mm). Within the fine earth fraction, soil particles are further divided into sand, silt and clay. These three, basic soil classifications differ from one another markedly via their respective properties such as size, specific surface area, ability to hold water or nutrients as well as cohesiveness and malleability (Brady & Weil, 2010). In addition, the relative amounts of these three soil particles can influence several other important soil properties such as soil organic matter level, decomposition of organic matter, compactability, risk of erosion, shrink-swell potential and even resistance to pH change. Whereas soils high in sand may drain well, they generally do not contain many plant nutrients. Clay-rich soils on the other hand have very high water holding capacities but the decomposition of organic matter in these soils may be very slow. Understanding all of these properties is essential to planning appropriate land-use for a given tract of land; building homes or buildings on a Vertisol containing high amounts of shrink-swell clays would be dangerous but if the soil texture is consulted beforehand, potentially disastrous situations like this could be avoided.

Methods

For this particular lab, we determined soil texture by the hydrometer method which is explained below.

a) 50 g of the first soil sample (Pit #5) were weighed and then put into a beaker along with 100 ml of SHMP and at least 50 ml of distilled water

b) Once well mixed, the Pit #5 soil sample was quantitatively transferred to a larger beaker that was mixed for approximately 3 minutes.

c) After mixing, the Pit #5 soil sample was transferred to a larger cylinder where distilled water was added until the final volume reached 1000ml.

d) An agitation plunger was used to mix the suspension for 3 minutes; after the 3 minute mark, the plunger was removed. Once 67 seconds had passed once the plunger was removed, a hydrometer was inserted to obtain a reading. This procedure was repeated two more times (for a total of three hydrometer readings).

e) At least 11 hours after the first three hydrometer readings, the soil sample was agitated again by the plunger and another hydrometer reading was taken.

Methods continued

f) In addition, corrections were calculated and noted for the temperature and the density of water (due to changes in viscosity due to temperature temperature, and the addition of other solutions, such as SHMP and anti-foaming agents).

Results

From on our data, the soil sample from our field site was classified as a loam via the soil textural triangle. Table A illustrates the measures taken through the hydrometer method which were used to classify the soil texture. Table B shows the results of other soil samples from the soil study area along with their respective percentages of sand, silt, and clay.

Table A. Pit #5 Hydrometer analysis

Soil Name	Pit #5 Soil Sample
Soil Weight (g)	50.00 g
Average 67-second hydrometer reading, g/L	40.33 g/L
Temperature of suspension (˚C)	25.5 ˚C
Temp. Correction	1.875
Density Correction	3 g/L
Corrected 67-second reading, g/L	35.455 g/L
11 hour hydrometer reading, g/L	11 g/L
Temperature of suspension (˚C)	22˚C
Temp. Correction	1
Density Correction	3 g/L
Corrected 11 hour reading, g/L	7 g/L
Grams of sand	14.545 g
Grams of clay	7 g
Percent sand	29.09%
Percent clay	22%
Percent silt	48.91%
Soil textural class	Loam

Discussion

The result of loam for the Pit #5 soil sample makes sense since the particular sample comes from a field in the Palouse, well-known for its silt-rich Mollisols. Loams are arguably ideal soils for plant growth since they have moderate drainage and moderate water-holding capacity (neither too wet nor too dry), contain moderate to high amounts of organic matter and have moderate inherent fertility. Soil samples from the other pits had similar results as well, with the relative amounts of sand, silt, and clay being quite uniform except for Pit 3 where the clay percentage was almost 10% higher than other samples. It could be that Pit 3 contained a high amount of clay, depending on the depth at which the sample was taken. However, 10% is quite a significant amount and it

SOIL TEXTURE CONTINUED

Table B. 5 study site soil sample hydrometer method results

	Initial Soil (g)	Corrected 67 Second Reading (g/l)	Corrected 11 Hour Reading (g/l)	% silt and clay	% sand	% clay	% silt	Total	Soil Textural Class
Pit 1	50.1	33.7	12.0	67.32	32.68	23.97	43.35	100	Loam
Pit 2	50.0	33.1	13.0	66.16	33.84	26.00	40.16	100	Loam
Pit 3	50.0	36.6	16.0	73.25	26.75	32.00	41.25	100	Clay Loam
Pit 4	50.2	30.6	11.0	60.98	39.02	21.92	39.06	100	Loam
Pit 5	50.0	35.5	11.0	70.91	29.09	22.00	48.91	100	Loam

Discussion continued

could mean that the hydrometer readings taken for this pit may have been slightly inaccurate. What seems to be like large changes in relative proportions actually amounts to a subtle change in classification, which infers the importance of the properties of sand, silt, and clay.

Possible errors in the final result could have occurred from incorrect steps taken during procedures (eg quantitatively transferring soil samples), reading the hydrometer incorrectly or simply math errors in determining amounts or percentages of sand, silt, and clay in the soil samples.

4. SOIL PHYSICAL PROPERTIES: bulk density, porosity, gravimetric and volumetric water content

Introduction

Soil bulk density is an important measurement that quantifies the mass of a unit of volume of dry soil which includes both solids and pores. Soils typically contain about 50% pore space and 50% solids; if the pore space is significantly lower, it may mean that the soil has undergone compaction or some other activity. Soil pores are very important since they allow infiltration of water, diffusion of air, and easier penetration of roots. Along with soil texture, organic matter content and soil structure can affect a soil's bulk density and in turn play key roles in determining the best use for a given soil. For example, soils with a high bulk density (such as Vertisols) may not be well suited for cultivation of crops that prefer fine, granular soils that can be penetrated easily. Porosity also relates strongly to bulk density since it is a measure of the pore space of a soil that is the portion of the soil volume occupied by air and water. To relate these, incidences of compaction can increase bulk density and lower porosity. Understanding bulk density and porosity can greatly aid one in determining the stability of soil in response to loading forces

Introduction continued

from traffic, tillage or building foundations (Brady & Weil, 2010). Water is yet another useful measurement, or rather volumetric and gravimetric water content. The behavior of water in soil is all related to energy relationships and gradients which in turn affect the retention and movement of water in soil, its uptake and translocation in plants and its eventual loss to the atmosphere via evapotranspiration. Soil texture greatly affects these properties; clay rich soils tend to have higher water holding capacities and drain slowly while sand-rich soils have low water holding capacities and drain rapidly. Soil water content is simply a measure of the weight or volume of water present in a given weight or volume of soil. Whereas volumetric water (Θv) content expresses water content in terms of volume, gravimetric water content (Θg) expresses it in terms of weight. When water content measurements are done in conjunction with bulk density and porosity, a greater understanding of the soil's pore space can be ascertained. For example, clay soils contain high water content which in turn reflects several properties of clay, such as its high total pore space, large storage capacity, extremely small pore size, low matric potential and strong water retention force. Water content is definitely an important part of any land use plan; understanding this property can help in determining (for example) the most appropriate plants to cultivate in an area and how often or how much one should irrigate.

Methods

For this particular procedure, we determined the bulk density of our soil sample from pit #5. Water content was not measured.

a) Using a soil sampler, we took at least two samples from soil Pit #5 of the study site.
b) We carefully removed soil from the sampler (without allowing empty spaces to form) to the standard plastic cylinder, making

SOIL PHYSICAL PROPERTIES CONTINUED

Methods continued

sure that the plastic cylinder was filled to the top with soil.

c) In the lab, we removed the soil from the cylinder and placed it in a soil moisture tin.
d) We baked the soil moisture tin at 105˚C for at least 24 hours.
e) We recorded the oven dried mass of soil from ring for bulk density calculations.

Results

Based upon our soil sample, we collected the following measurements.

Table C. Bulk density results from pit #5

Oven dried mass of soil from ring (g)	224.39 g
Height of soil core (cm)	7.6 cm
Internal radius of soil core (cm)	2.25 cm
Core volume ($\pi r^2 h$)	120.87 cm
Bulk density (g/cm^3)	**1.86 g/cm^3**

Discussion

A high bulk density for Pit #5 may make sense, if it were to be compared among other samples from different pits across the sample area. Since Pit#5 was located at the bottom of the hill (at the bottom of the toe slope and possibly in the flood zone), so a higher bulk density may make sense due to accumulation of soil, sediments, etc. from the back slope. Also, traffic in this area may have led to compaction. If the bulk density of this sample is truly this high, then it may mean that root penetration, as well as air and moisture penetration, could be difficult. Macropore space may be limited or compromised. When researching future uses for this area, this high bulk density should be considered since it may act as a limiting factor for certain crops or plants.

Possible errors in the final result most likely occurred when quantitatively transferring soil samples from the soil sampler to the standardized soil sample cylinder. The soil core was not preserved completely and therefore there may be additional pore space calculated in the bulk density. In other words, the bulk density calculated may be lower than in reality. However, the bulk density is surprisingly high (1.86 g/cm^3) whereas typical bulk densities range between 1.0-1.8 g/cm^3 which may mean that errors were made elsewhere (such as in measuring the soil sample cylinder).

5. SATURATED HYDRAULIC CONDUCTIVITY

Introduction

As explained in the previous section, differences in water potential between two areas causes water to flow (i.e. a gradient is created). Water always moves from areas of high pressure (or high free energy) to low pressure (or lower free energy). However, the ease at which the soil water moves is directly tied to the size and distribution of individual soil pores. In general, the larger the pore size (or the greater the porosity), the faster the flow of water. This can be measured through the saturated hydraulic conductivity. This measurement is based upon water moving through a soil profile due to the gravitational potential gradient. In particular, this measurement can give insight into the macropore content of a given soil; when a soil is saturated, the macropores are the site of the majority of the water flow. That is to say, soils that contain many macropores have high saturated hydraulic conductivity (such as sandy soils) whereas compacted clays (which contain micropores) have very low saturated hydraulic conductivity. This particular measurement is important to take when evaluating a soil since it can give valuable insight into drainage capabilities of the soil; different land uses (ranging from landfills to septic tank drain fields to agricultural uses) require different saturated hydraulic conductivity. For example, landfills require a soil that has a very low saturated conductivity since any moisture and contaminants want to be kept from leaching into the soil below.

Methods

The following steps outline the procedure used to obtain measurements of the saturated hydraulic conductivity of our study site by use of the Guelph Permeameter.

a) We excavated a well hole to depth of at least 15 cm.
b) After setting up the Guelph Permeameter and filling the reservoir completely with water, we lowered the Permeameter into the prepared well hole.
c) We made sure that both reservoirs were connected and raised the air inlet tip to set up the first well head height at 5 cm.
d) Using a timer, we released water and time the rate of fall at 10 second intervals. Once the rate of water fall into the reservoir did not change for three consecutive time intervals, a steady state had been reached; in addition, this rate at the steady state was the RI at H1 (5 cm).
e) We repeated the procedure except for the fact that we changed the first well head height to 10 cm. Again, using a timer, we released water and timed the rate of fall at 10 second intervals. Once a stable rate had been achieved (steady state- no change in rate for three consecutive time intervals), the R2 for H2 (10 cm)

SATURATED HYDRAULIC CONDUCTIVITY CONTINUED

Methods continued

had been determined.

f) Finally, we calculated the field saturated hydraulic conductivity using the collected data.

Results

The following data was recorded while using the Guelph Permeameter to determine saturated hydraulic conductivity.

Guelph Permeameter Field Data:

For the 1st set of readings, R1ss = R1/60 = 0.3cm/sec

For the 2nd set of readings, R2ss = R2/60 = 1 cm/sec

K_s = [(0.0041)(reservoir constant)(R2ss)]-[(0.0054)(reservoir constant)(R1ss)]

K_s = [(0.0041)(35.73)(1)]-[(0.0054)(35.73)(0.3)]

K_s = 0.0886104

Discussion

According to Table 5.3 in the Lab 7 handout, the soil sample tested in the field should have been around 5×10^{-4} since it is a moderately permeable soil. However, the K_s calculated (0.0886104) is far larger and is instead in the range of beach sand (1×10^{-2}). However, this high value may be attributed to the fact that the soil sample may have had a matric potential higher than usual due to prolonged dry weather. In other words, water flows more readily flow from areas of high matric potential (wet soil or water from the Permeameter itself) to areas of low matric potential (dry soil). Considering the extremely dry conditions in the Palouse region, it may be possible that a high matric potential in as well as a matric potential gradient as a key driving force could have given such a high K_s. However, possible error area could have resulted from the procedure itself, especially when determining the steady state of the rate of fall. Because this measurement was most likely inaccurate, it is difficult to say how useful it will be in our land management. However, based upon the Lab 7 handout, we do know that the average saturated hydraulic conductivity for loam is probably around 5×10^{-14} cm/s, which is considered suitable for most agricultural, recreational, and urban uses calling for good drainage. Also, it should be noted that the Palouse is home to dry land farming; no irrigation is used and instead farmers rely upon the moderate water holding capacity of soils here to store water for use throughout the year. In addition, a hardpan is found in some areas causing a perched water table, so drainage is still of concern. Land planning should be sure to keep this in mind since it can cause instability.

6. SOIL ORGANISMS

Introduction

Soil may seem like a mix of pores, water, colloids, varying amounts of sand, silt, clay and the occasional nutrient, but it is actually teeming with life. Various flora and fauna inhabit soils, whether they take root at the surface or burrow deep down in the profile. Everything from macrofauna (such as gophers and mice) to microflora (like algae, fungi, and root hairs) to innumerable bacteria live soils. Together, these communities of flora and fauna assimilate plant and animal materials, create soil humus, recycle carbon and mineral nutrients and support plant growth (Brady & Weil, 2010). Moreover, these organisms help support a given ecosystem's stability (the soil's ability to continue to perform certain functions during varying environmental conditions) and resilience (the degree to which a soil can "bounce back" after a disturbance) (Brady & Weil, 2010). For example, earthworms are a "staple" organism (ecosystem engineer) to many soils; they play a crucial role in terms of a soil's fertility and structure by ingesting soil and creating casts (rich in organic matter and nutrients), as well as burrows (easier penetration for air, water, and roots). However, if a soil is disturbed through mechanical means (such as compaction from farming equipment) or chemical additives have changed the relative composition of the soil (via salinization or a change in pH), the diversity and sheer number of soil organisms could be affected. Other factors affecting the abundance of soil organisms includes oxygen moisture and temperature (Brady & Weil, 2010). In turn, this could affect the various ecosystem functions that these organisms carry out as well as the stability and resilience of the soil ecosystem as a whole. Many soil-management practices (ranging from the use of fumigants to monocropping to plastic mulches) can have detrimental effects upon the biological diversity and activity of various soil organisms. Therefore, it is wise to learn about the current composition of soil flora and fauna as well as comparing it to the past soil organism diversity in the area in order to implement a soil management plan that sustainably benefits from current soil organism diversity but also acts to conserve or protect it.

Methods

Soil organisms for Pit #5 were obtained by the Burlese-Tullgren Funnel Extraction method as described below.

a) Obtain approximately one kilogram of soil from the field sample site

b) Put the soil in the bottom of the Berlese-Tullgren funnel on top of the mesh cloth and metal grid.

c) Place the lid on and turn on light for at least 24 hours

d) Attach a mason jar filled with about two centimeters of 70%

SOIL ORGANISMS CONTINUED

Methods continued

ethanol to the bottom of the funnel

e) After at least 24 hours, remove mason jar and extract organisms via a transfer pipet to view them under a microscope.

Results

Only one soil organism was identified (Figure E); it was most likely a species from the *Gastropoda* class.

Figure E. Gastropoda sketch from Soil Pit #5

This is a very broad class of organisms that includes snails and slugs. Depending upon the habitat as to where a particular *Gastropoda* species is found, these organisms can vary in their diet which ranges from simple herbivory to predatory and scavenger feeding habits.

Discussion

As expected, we did not find a high abundance nor a high diversity of soil organisms due to a prolonged dry period across the Palouse. Because various organisms, specifically earthworms (for which the Palouse is known!), need a certain amount of soil moisture to survive, it is probable that many of the organisms in our field site migrated deep down the soil profile (again, due to drought) to find an environment moist enough to support them- a depth far beyond which we were able to sample. However, we can imagine what life below the soil surface would look like. According the Palouse Prairie Fund, soils throughout the Palouse (like our study site) provided habitat for giant earthworms that reached up to 3 feet in length (*Palouse Prairie Fund*, 2012)! The Palouse ecosystem is highly dependent upon the moisture-holding capability of the loam soil structure; plants and other organisms are able to tap into moisture reservoirs even after prolonged dry periods. However, if droughts begin to occur at a greater frequency on the Palouse (in addition to land-use planning that reduces organism diversity and activity), it can be inferred that there will certainly be effects upon the overall fertility, structure, stability and resilience of the soil since soil organisms may be forced to move deeper along the profile to find ideal conditions or disappear altogether (and their ecosystem functions with them).

7. SOIL CATION EXCHANGE CAPACITY (CEC)

Introduction

Not only is the CEC important in classifying soils, it also can give insight into the fertility and environmental behavior of soils (Brady & Weil, 2010). In general, the CEC of a given soil is dependent upon the types of abundance of colloids within the sample as well as pH. Many cations, specifically K^+, Na^+, Mg^{2+}, and Ca^{2+}, function as important plant nutrients; therefore, the higher CEC of a given soil, the better the long-term fertility of the soil. Specifically, hydrogen ions from root hairs and microorganisms replace nutrient cations form the exchange complex which in turn are forced into the soil solution, where they can be assimilated by the adsorptive surfaces of roots and soil organisms, or removed by drainage water (Brady & Weil, 2010). By understanding a given soil's CEC, one can develop a soil management strategy that both benefits from the cations in the soil solution (long-term fertility) but also strives to preserve the nutrient level of the soil and therefore the long-term sustainability of the given soil.

Methods

In order to determine the CEC of Pit #5, we used a titration procedure as outlined below.

a) We obtained 5 g of soil pit #5 (crushed with mortar and pestle) and inserted it into a labeled 50 ml centrifuge tube.

b) We saturated the exchange sites of the soil sample by adding 30 ml of 1 M HCl to the tube. After shaking gently for 5 minutes, we transferred the sample and centrifuged it for 5 minutes at level 25. Afterwards, we removed the soil sample and discard supernatant.

c) We added 30 ml of DI water to wash all H^+ not on exchange sites from the soil. Again, we shook the tube for 2 minutes, then transferring and centrifuging it as described previously. We then discarded the supernatant and repeated this step once more.

d) In order to displace H^+ on exchange sites with Ca^{2+}, we added 30 ml of 1 M CaOAc. We shook the tube for 2 minutes and centrifuged it as described previously. However, we then removed and saved the washings in an Erlenmeyer flask. We repeated this step once more. After transferring the washings to an Erlenmeyer flaks, we added 5 drops of phenolphthalein.

e) Finally, we titrated 0.1 M NaOH carefully into the Erlenmeyer flask until the endpoint was reached (neutralization).

Results

Based upon our results, soil pit #5 has a CEC of 22.5 $cmol_c/kg$. Details regarding this result can be seen in Table D and the associated dimensional analysis equation.

CATION EXCHANGE CAPACITY CONTINUED

Table D. CEC of Soil Pit #5

Soil Name	Weight (g)	NaOH (ml)	NaOH (M)	CEC ($cmol_c$)
Pit #5	5.00	11.25	0.1	22.5

$$\frac{\mathbf{11.25\ ml\ NaOH}}{\mathbf{5\ g\ soil}} \times \frac{\mathbf{0.1\ mol\ NaOH}}{\mathbf{L}} \times \frac{\mathbf{1\ L}}{\mathbf{1000\ ml}} \times \frac{\mathbf{1\ mol_c}}{\mathbf{1\ mol\ NaOH}} \times \frac{\mathbf{100\ cmol_c}}{\mathbf{1\ mol_c}} \times \frac{\mathbf{1000\ g}}{\mathbf{1\ kg}} = \frac{\mathbf{22.5\ cmol_c}}{\mathbf{kg\ soil}}$$

Discussion

CEC is a very important property of soils that is key to understanding the long-term fertility of a given soil sample. Because CEC concerns the net negative charge on colloids and the attraction they exhibit for positively charged ions such as Ca^{2+},Mg^{2+} and K^+, CEC naturally gives an insight into the degree at which key nutrients (such as the cations previously listed) are available to plants in the soil solution. Soil colloids therefore increase the retention of plant nutrients and protect them from being leached; however, if the CEC is high enough, then these nutrients may be linked so strongly with colloids that plants may not be able to extract them. Mollisols usually have a CEC around 24 $cmol_c$/kg; with this in mind, our result of 22.5 $cmol_c$/kg sounds reasonable. However, there is certainly a margin of error since some of the soil sample was lost when discarding the supernatant during the CEC determination procedure. In addition, this measurement may allow us to interpret the long-term fertility of our soil site; at 22.5 $cmol_c$/kg, our soil site seems to have a high capability to retain and protect needed nutrients from leaching. Therefore, it could support many plant-based soil management plans, whether they be agriculture or restoration ecology. However, special attention should be upon maintaining an appropriate pH since this could potentially affect our study site's CEC by decreasing the number of exchange sites available to cations and thereby risking the leaching and loss of valuable plant nutrients.

8. pH AND SALT-AFFECTED STATUS

Introduction

Described as a master variable, soil pH directly affects a large range of chemical and biological properties related to soil. Not only does pH affect the root uptake availability of elements but it is also influences the rate of various biologically-related processes, such as decomposition by bacteria. Moreover, soil pH affects the mobility of nutrients and pollutants via the rate of biochemical breakdown, solubility and adsorption to colloids (Brady & Weil, 2010). High or low pH can have dramatic effects in terms of the availability or the leaching of various plant nutrients, such as Ca^{2+}, Mg^{2+}, K^+, and Na^+. Finally, the active, exchangeable, and residual acidity of a soil can also help buffer it against changes in pH.

Some soils may have an acidity that is too high for plant life or other soils may be too alkaline and cause deficiencies of certain micronutrients. Therefore, it is important to understand the pH of a given soil in relation to the pH needs of plants (or crops) and organisms that inhabit the same soil. If the pH of the given soil is radically different from what the soil used to be or it is evident that plants need a higher or lower pH to flourish, remediation efforts may need to be considered, such as the application of $CaSO_4$ or $CaCO_3$ (increase pH). As mentioned earlier, pH directly affects CEC; therefore, in order to ensure the sustainability of the given soil, special attention must be given to pH.

Salt is another area for concern in soils. Development of salt-affected soils usually develops in arid or semi-arid areas where evaporation exceeds precipitation or in low, flat areas with high water tables that may be subject to seepage from higher elevations (Brady & Weil, 2010). Soils containing salt can be classified several ways, each with their own properties and concerns. Saline soils (EC greater than 4dS/m) can interfere with plant growth by affecting osmotic water potential (Brady & Weil, 2010). Saline-sodic soils may contain excess salt and sodium levels and can negatively influence infiltration of water by encouraging dispersion among soil particles. Sodic soils are the most worrisome since they are the most difficult to remediate. These soils have high levels of sodium on the exchange complex (poor water and air permeability); moreover, these soils have high pH levels causing organic matter to disperse or even dissolve. Although some sodium or salts in soil may help a soil in terms of flocculation, aggregate stability and aeration, certain properties associated with saline or sodic soils can be detrimental to plant survival and crop yield. Therefore, creating a soil management plan that takes salt-affected status into account can reduce the risk of overly saline and/or sodic conditions from developing or help remediate these conditions if they already exist.

Methods

In order to obtain the pH and EC values for our Pit #5 soil sample, we used an electrometric technique for pH and a soil electrical conductivity measuring device for EC.

pH AND SALT-AFFECTED STATUS CONTINUED

Methods continued

a) We placed 25 g of soil into a labeled cup and added 25 ml of deionized water.
b) We mixed the solution thoroughly with a stirring rod and let the suspension settle over the period of 1 hour.
c) After filtering the solution via a vacuum filter flask, we placed the solution in a small container.
d) By using a pH electrometric method and a soil electrical conductivity measuring device, we determined the pH and EC of the solution of the soil sample
e) Based upon the pH and EC results, we classified the soil sample as sodic, saline, saline-sodic or neither.

Results

Below in Table E, the results for the pit #5 soil sample are outlined.

pH (from electromagnetic technique)	5.77
pH (from EC measuring device)	6.92
pH (from Analytical Sciences Lab)	6.3
EC (from EC measuring device)	.2153 mS/cm
Soil salinity Classification	neither saline nor sodic

Discussion

The classification of a salt-affected soil is based upon pH, electrical conductivity (the greater the sodium content, the higher the electrical conductivity) and ESP. The final classifications of Pit #5 were surprising but were probably not entirely accurate either (due to technological difficulties). The relative acidity of Pit #5 from the electromagnetic technique was not expected; Mollisols are usually neutral to alkaline soils. The measurement from the EC measuring device (6.92) seems more probable but it should be known that the value of 6.92 remained the same regardless of what soil solution was tested. The question is then, what made the results so acidic? Was it just the measuring device or is there something in the soil sample that we should be concerned about, such as possible feedback between the cover crop and the soil? The salinity on the other hand was low (<4dS/cm) but it was still of some concern. Although the soils in this region are quite deep, there is an impermeable subhorizon in many areas, which may mean that salts could accumulate if the input exceeds the drainage of water. On the other hand, the Palouse is a dryland farming region, so this may not be such a high risk. In any case, it is worth noting and making sure to implement or mention procedures in a soil management plan to reduce the risk of salinization.

Also, it is important to identify possible sources of error for the pH, which could include: technological difficulties with the equipment

Discussion continued

and inaccurate readings due to ineffective use of the vacuum filter (some soil particles made it past the funnel and clouded the solution, possibly affecting the accuracy of the pH results).

10. SOIL CARBON, NITROGEN AND NUTRIENT STATUS

Introduction

The amount of organic carbon, nitrogen and nutrient status are the final factors that we evaluated concerning our field site. In combination, these factors, as well as all the previously discussed factors interact with one another and can greatly affect numerous properties of a soil, ranging from physical aspects such as texture and structure to chemical aspects and processes, such cation exchange capacity.

Organic matter content is highly desirable in soil since it helps improve root and water penetration as well as air diffusion (through providing a higher degree of porosity, aggregate stability). Moreover, humus and organic matter can act as very powerful colloids and have a very high CEC, thereby helping to ensure a long-term amount of soil fertility. In addition to ameliorating soil structure, organic matter increases the moisture holding capacity of soils, reduces soil erosion, buffers against changes in pH, supports the diversity and biological activity of soil organisms, and determines plant nutrient availability. Carbon in organic matter is also important as a nutrient which can limit microbial activity; that is to say, carbon should hold a certain ratio to nitrogen to support microorganisms and a sustainable rate of decomposition (24:1 in food sources for microorganisms for example).

As described previously, carbon content in soil is also linked to nitrogen. In fact, scarcity of N is the most widely occurring nutritional limit on the productivity of terrestrial ecosystems (Brady & Weil, 2010). Nitrogen is part of all proteins- including the enzymes, which in turn control virtually all biological processes. Therefore, a certain degree of nitrogen should be maintained in a given soil to ensure peak plant growth.

Other nutrients that are important include sulfur, phosphorus and potassium. Sulfur is a crucial part of certain essential amino acids, vitamins, enzymes, and aromatic oils; this element is especially important to the legume, cabbage, and onion families (Brady & Weil, 2010). Phosphorus is a key component in adenosine triphosphate (ATP) as well as DNA, RNA, and phospholipids. Moreover, is plays important roles in photosynthesis, nitrogen fixation and other processes (Brady & Weil, 2010). Finally, potassium is known to activate over 80 different enzymes which relate to various processes ranging from metabolism to photosynthesis.

SOIL CARBON, NITROGEN AND NUTRIENT STATUS CONTINUED

Methods

In order to determine the organic matter content of our pit #5, we used the loss on ignition procedure as explained below.

a) We first tared the ceramic crucibles by placing them in an oven at 105˚C for at least 16 hours. Afterwards, we placed them in a desiccators and cooled for 30 minutes, then weighing them again to an accuracy of 0.001g.
b) We measured out approximately 10-15 g of soil in a tared ceramic evaporating dish (use a 4-5 place electronic balance)
c) We then dried the sample overnight by placing it in an 105˚C oven.
d) Later, we removed the sample, cooled it and weighed it to an accuracy of 0.001 g.
e) Putting the sample into a cold muffle furnace, we increased the temperature to 400˚C and heated the sample for around 16 hours.
f) Once the furnace cooled to 100˚C, we removed the sample and let it cool for 30 minutes. Once cooled, we weighed the sample again to an accuracy of 0.001 g.
g) Finally, we calculated the organic content (%).

Note: organic matter, nitrogen and other nutrient content was also determined by the Analytical Sciences Lab (which is outlined in Table G).

Results

Below in Table F, the organic matter content results from the loss on ignition procedure for the pit #5 soil sample are outlined.

Sample	Crucible (g)	Soil (g)	Total (pre-furnace) (g)	Final (post-furnace) (g)	Calculated organic matter content (%)
Pit #5	93.86	60.00	153.86	151.56	3.83

Table G. Nutrient Status Results from Analytical Sciences Lab

Available Potassium	Available Phosphorus	Nitrogen-Nitrate + Nitrite	Nitrogen-Ammonium	Organic Matter	pH
190 μg/g	22 μg/g	13 μg/g	3.7 μg/g	3.0%	6.3

Discussion

Since Mollisols (such as our soil site) are typically very high in humus and organic matter (as is evident by the large A Horizons seen in Figure D), the organic matter content from the loss on ignition as well as the analytical sciences lab was not a surprising amount. Although 3.0-3.8% may seem like a high value, the location of soil pit #5 (which is at the toeslope/floodplain area) could result in accumulation of organic matter weathered from the shoulder and summit of nearby hills. Such a high organic matter content, however, is a beneficial and positive indication of this soil; higher organic matter content helps tremendously with soil structure, texture, water-holding capabilities, root and water penetration, cation exchange capacity and more.

In terms of nutrient status, little to no remediation should be done to ensure a healthy, sustainable soil. Several scenarios with different crops (such as lentils and grass seedlings for conservation programs) were run on this particular soil sample. For lentils, no additional potassium or phosphorus was needed; in fact, our soil sample seemed to have more than enough of both of these nutrients. Nitrogen did not need to be added either since lentils fix nitrogen from the atmosphere. Even so, the nitrogen levels in this soil are sufficiently high enough to support some crops. Grass seedlings did however, require a small nitrogen input. If more “nutrient-needy” crops were to be considered for our soil site, nitrogen could be of a concern. A possible solution (to ensure sufficient nitrogen levels) would be to plant nitrogen-fixing cover crops. Other measures to reduce the chance of severe nutrient losses could be to cultivate species native to the area, such as various native Palouse grasses, or to practice crop rotation.

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