SOIL HEALTH & NUTRIENT MANAGEMENT
FOR IMMIGRANT FARMERS
2-Day Train-the-Trainer Workshop

THE GOOD ACRE
1790 Larpenteur Avenue West,
Falcon Heights, MN 55113
SOIL HEALTH & NUTRIENT MANAGEMENT FOR IMMIGRANT FARMERS

2-Day Train-the-Trainer Workshop
@ The Good Acre

MONDAY
September 19, 2016

10:00 - 12:00
Welcome and Lunch

12:00 - 1:00
Soil Basics

1:00 - 2:45
Soil Quality and Organic Matter

2:45 - 3:00
Break

3:00 - 4:00
Cover Crop Basics

TUESDAY
September 20, 2016

9:00 - 9:30
Breakfast

9:30 - 11:15
Cover Crop Termination:
Matching tools with crops; collecting plant samples
to calculate nitrogen (outside)

11:15 - 12:00
Nutrient Management
(reading and using a soil test report)

12:00 - 2:00
Lunch and Discussion:
Building on experience: engaging and mentoring
immigrant farmers in cover crop use

2:00 - 3:00
Tour The Good Acre (optional)
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SOIL BASICS

By Peyton Ginakes

WHAT YOU WILL LEARN

• What is soil made of?
• What does each part do?
• How does each part help plants?
Soil Basics

Soil Health & Nutrient Management for Immigrant Farmers

WHAT IS SOIL

In agriculture, we think of it as our BIGGEST resource. Without soil, we can’t grow anything! But what else does it do, as a resource?

• Holds up people, buildings, roads, plants, and animals
• Gives plants air and water
• Hosts a LOT of microorganisms!

It is full of living things. In just ONE teaspoon (demonstrate) of soil, there can be more than 600 million organisms, many yet undiscovered - several microscopic miles of fungi, more than 10,000 individual protozoa, and 20 to 30 beneficial nematodes.

WHAT HAVE YOU DONE TO HELP SOIL?

When we talk about resources, we often think of ways to conserve or protect them so that we can keep benefitting from them for a long time.

WHAT’S IN SOIL

Soil has 4 major components:

• mineral particles
• organic matter
• air
• water

This means that half of soil by volume is made of solids, and half is made of pore space.

Mineral particles are individual pieces of soil, and they make up the bulk of solid soil volume – about 45-50%. Together, they make up soil texture according to their sizes. There are three size classes: sand is the biggest, silt is in the middle, and clay is the smallest.

Soil is only 1/2 solid

Mineral particles are divided into 3 size classes:

• sand
• silt
• clay

The amount of each particle size determines soil “texture”
MINERAL PARTICLES

SAND
- 0.05 - 2.0 mm in size
- Sometimes visible to the eye
- Gritty when wet and dry
- Drains quickly
- Irrigation is especially important due to drainage

Since it is the largest, sand is usually visible to the naked eye. It feels gritty when it is dry and when it is wet. Since the pieces are so big, it drains rather quickly, too - we'll see more about this in a minute. What have you all noticed about sand, either here or on your farm?

SILT
- 0.002 - 0.05 mm
- About as thick as a strand of hair!
- Feels like flour
- Don’t till more than necessary, or this good soil will get washed away!

Silt is the next largest particle size. It is about as thick as a strand of hair, and the individual pieces are tough to see/often impossible. Silt usually feels very fluffy, and when it is wet, it is very smooth and floury.

CLAY
- The smallest particle size
- Less than 0.002 mm
- Invisible to the eye
- Feels sticky when wet
- Dries slowly in the spring; plan accordingly!

Clay is the smallest soil particle size. Individual pieces of clay are impossible to see, and when it is wet it is somewhat sticky. It is also very slow to drain. Have you all noticed anything about clay?
Soil Basics

1

Soil Health & Nutrient Management for Immigrant Farmers

This is a well-known image for soil scientists – we call it the “soil triangle”. It is a way to see what your final soil texture is. First you have to know the composition of your soil, though. Once you know that you find those percents on each side, then you see where they meet. (Draw out arrows on board).

So let’s practice:
If you have a soil that is 35% sand, 40% silt, and 25% clay, what is your soil texture? It’s a loam! A loam, or some type of loamy soil, is ideal. Unfortunately, we cannot change soil textures through management, because soil particles are made when rocks are weathered, over the course of anywhere from thousands to billions of years. Still, we can make most soil types work for farming by influencing other components.

Does anyone know what their soil texture is or have an idea based on how it feels?

The main reason that we care about soil texture is because particle sizes determine pore sizes.

We are going to do a quick experiment to see why pore sizes matter. Here we have three different soil types: a sandy soil, a clayey soil, and a soil with a lot of organic matter. I’m going to pour water in each one to pretend that we just had a big rain. After a couple minutes, which soil do you think will have the most water that has passed through? Let’s see.

Pore space is all the pockets between the solid parts of soil. Let’s zoom in a bit and pretend that tennis balls represent sand particles. Silt has to be smaller than tennis balls then, right? Silt is like marbles. And clay is way smaller. Clay particles also tend to be flatter too, like sheets rather than roundish grains. So those are a lot like poker chips. Which soil particles have the most space between them? Sand! So let’s look back at our experiment – and sure enough, water has gone through the sand most quickly! That’s because it has the most space to move through, right? What about the others? Clay takes a long time to move through, there is not much space between these particles at all.

• “Loam” soil is ideal
• Soil texture cannot be changed through management!
• Soils were made over billions of years through the natural process of weathering

SOIL TEXTURE

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• “Loam” soil is ideal
• Soil texture cannot be changed through management!
• Soils were made over billions of years through the natural process of weathering
Soil Basics

We will talk about Soil Organic Matter (SOM) more later, but we want to show you ahead of time that organic matter really increases the amount of water that soil can hold, which is awesome. SOM is the other solid part of soil, and it can make up to 5% of soil by volume. It is super important! Holding more water is just one benefit we get from SOM, and luckily, unlike soil texture, we can manage the amount of soil organic matter that is in our soils.

Let’s focus on pore space for a minute. We know now that this is influenced a lot by soil texture right?

Usually, pore space is about half air, half water - and that’s ideal for a lot of the things that live in soil. When this is the case, water sort of sticks to the solid particles, and air is in the bigger pores. The proportion of air and water in soil pores is a lot like a tug-of-war - when it rains, there is more water, and there is more air when it’s been dry for a while.

But plants need both in the soil! Why?

Balance is very important. If you have a clayey soil, you can use management practices that help add air channels and pockets; if you have a sandier soil, it can be managed to better hold water.

### Soil Organic Matter (SOM)

organic = materials that were once alive, either recently or thousands of years ago

Mostly a source of carbon (C) and nitrogen (N), but can also provide other nutrients - very nutritious!

More on this in the next unit...

### Soil is only 1/2 solid

Organic Matter can make up anywhere from 1 to 5% of soil

It’s VERY important!

We can change how much is in soil with how we manage soil

### Soil is half pore space

Soil pore space is made up of air and water:

- when it rains, it’s more water than air
- when it’s been dry, it’s mostly air.

### Why do plants need both air and water?

SOIL ORGANIC MATTER (SOM)

We will talk about SOM a lot in our next unit, but let’s just quickly touch on what soil organic matter actually is. In this case, we don’t mean organic like “certified organic” - we mean it as chemically organic. This means that it was at some point alive, as a plant or animal - and these can have originated anywhere from a couple of weeks ago to thousands of years ago!

SOM is mainly made of carbon and nitrogen, two elements found in all living organisms. We will talk a lot about both of these elements, and focus on nitrogen management for crops in the next few units. You should also be aware that SOM has other nutrients too, just in smaller and more varying amounts. It is very nutritious for crops!
PARTICLE AND PORE SIZE DEMO

WHAT YOU NEED:

- 1 five gallon bucket or other large container
- 2 clear glasses, beakers, or other see-through glass containers of equal size
- Tennis balls
- Marbles
- Poker chips

QUESTIONS FOR CONVERSATION:

What shapes are these “particles”?
Sands and silts are rounded, grain shapes, but clays are more flat and elongated

Which of these has the most space between particles?
Sands > Silts/OM > Clays

Where are air and water in these types of soils?
Water adheres to particles, and air exists in larger pores

What happens when it rains in each soil type?
Water floods bigger and bigger pores, giving way as gravity lets out into water bodies like rivers and below-ground aquifers

Which sample will drain water more quickly?
The ones with larger pore space - in this case, sand

What role does drainage play?
We don’t want water to run out too quickly, because then crops can’t use it; alternatively, we don’t want to be saturated (like what happens in clays) because then crop roots “drown”

FILTRATION DEMO

WHAT YOU NEED:

- Clay soil sample
- Silt or high organic matter soil sample
- Sand soil sample
- Pop bottles (however many samples you have)
- Scissors
- 3/4 cups water

METHODS:

1. Cut the pop bottles all the way around 3 inches or so (all the same) from the top, leaving a top and bottom half
2. Remove the caps and invert the top half of the bottle into the bottom half
3. Place a cotton ball or pad into the mouth of the top half
4. Fill each top half with different soils up to 1-2 cm of the top of the surface
5. At the time of demonstration, pour the same amount of water into each soil-containing bottle top
6. Track which bottle has the most water in the bottom at a given time point (1 min, 5 min, etc.)
SOIL HEALTH

By Peyton Ginakes

WHAT YOU WILL LEARN

• What soil health means
• How organic matter makes soil healthy
• Why we should care about soil health
• What we do that affects health of soil
Soil quality is the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health.

Doran and Parkin, 1994.

This is a big definition of soil health that’s used pretty often, and here they use the word “quality” but it works for soil health too. It’s long, but it basically boils down to how soil helps ecosystems function, how it keeps its ecosystem alive, how it cleans air and water, and – what’s really important for farmers – how it helps plants and animals stay healthy.

Do you think of anything else when you think about soil health?

WHY SHOULD I CARE ABOUT SOIL HEALTH

Before we talk about how we can increase SOM, let’s talk about why we should care about soil health.

• Why do you care about having healthy soil?
• What conditions let crops do well?
• What is your soil like?
• When are crops healthy?
• How did you manage soil where you farmed previously?
• How do you manage it here?
• Are the practices you use different?
• What did you do when you farmed before to re-energize the soil?
• Have you discovered alternative methods that are more or less suitable for re-energizing soil here?

HAVING A MORE DIVERSE SOIL FOOD WEB CAN MEAN THAT INPUTS ARE BROKEN DOWN MORE EFFICIENTLY FOR PLANTS TO USE

This image is shows organisms that were found in just one tablespoon of soil! The point here is that having a more diverse soil food web can mean that inputs are broken down for efficiently for plants to use.

HAVING BETTER AGGREGATION DECREASES EROSION AND RUNOFF

What does aggregation refer to? It refers to the way and shape that soil is held together. We always want soil to stay together, especially when it’s wet out, because we don’t want it to wash away. We’re going to do a demonstration to show how well-aggregated soils hold together even when it’s wet.

Why else should we care about how soil is aggregated, or held together?

Having a diverse array of aggregate sizes also means there are lots of habitats for soil microbes!
HAVING GOOD SOIL QUALITY MEANS GOOD WATER FILTRATION!

Let’s do a similar demo to talk about water quality.

What do you think the water coming out of these soils will look like? What does it mean when water is muddy versus when water is clear?

Also, in water bodies like lakes, rivers, and streams, muddiness is considered pollution because fish and other water life don’t tolerate it well.

HAVING HEALTHIER SOIL CAN IMPROVE CROP RESISTANCE AGAINST PESTS AND ENVIRONMENTAL STRESSES

How many of you have gotten a cold when you haven’t been getting enough sleep or eating well?

When we are under stress, sometimes our immune systems get so tired that it can’t fight off what it could otherwise. Plants are the same way! When plants don’t have adequate nutrition from the soil, sometimes an insect or disease attack, or heat or drought, is too much for it to handle, and the plant can’t fight it off like normal. Healthy soils lead to healthy plants that can defend themselves.

Of course, all of this means that when we have healthy soils, our crops should be more productive, which is the most important part for farmers, right?

Are there other reasons we didn’t talk about why for you all care about keeping the soil healthy?
WHAT DO YOU DO TO HELP SOIL?

Here are some big ones:

1. Crop rotation is important because if you plant the same crop in the same place every year, diseases and pests can build up in the soil. This also adds a variety of inputs, and each type of crop takes different things out of the soil too.

2. Using appropriate equipment helps soil because over-working it with aggressive machinery can degrade soil structure and aggregation.

3. Adding inputs like compost, as well as manure, add those fresh, new SOM sources for microbes to turn into plant food.

4. Finally, and what we will talk about much more in the next section, is using cover crops to improve soil health in LOTS of ways. Cover crops keep the ground covered to protect soil from erosion, their roots take up excess water and nutrients to store them for later crop use, and they’re good for above-ground insects like bees. What we care about most is that when we kill cover crops and they go back into the ground, they release nutrients they accumulated and become that new SOM that microbes turn into plant food.
Chapter 3

Cover Crops

By Peyton Ginakes

What you will learn

- What a cover crop is
- Benefits and challenges of using cover crops
- How to select a cover crop
- Estimating how much N a cover crop is providing
All these different terms exist to describe cover crops. Sometimes people talk about green manures, which just means that it adds nutrients like we do with manure (mostly N), and sometimes we talk about catch crops. These are cover crops that tend to catch the extra nutrients before they get lost from the soil. It really doesn’t matter what we call them though, because they all do lots of things, so here we’ll just always say “cover crop.”

**H ow do cover crops help soil?**

**Why do we use cover crops, how do they help the soil?** How are they different from other resources that we can add to soil?

**What do you think?**

Cover crops add carbon-based organic matter to the soil, which commercial fertilizers don’t typically do. Compost and manure can add organic matter, but they are often too high in phosphorus, a nutrient we’ll discuss soon, when added to meet nitrogen needs. When too much phosphorus is in the soil, it can run into water bodies and kill aquatic life. Another difference between cover crops and synthetic fertilizers is that cover crops decompose slowly and their nutrient release is considered to match the timing of crop nutrient needs better than fertilizers.
HOW DO COVER CROPS HELP SOIL?

Brings in beneficial insects

Covers crops help soil in tons of ways. Of course this is aboveground, but cover crops bring in beneficial insects to the soil too. Importantly, some of those are spiders, mites, and other insects that hunt crop pests.

Increases mycorrhizae

Who has heard of mycorrhizae? Mycorrhizae are the channels that roots and fungi share, where the fungi expand plant roots to reach more resources. Cover crops expand these networks too! But we have to be careful, because tilling soil breaks up the networks.

Reduces nematodes

Cover crops tend to decrease the number of harmful nematodes in soil, which spread disease. Since nematodes need a constant food supply of plant roots, interrupting that with a plant root from a different plant family that it doesn’t eat causes their populations to decline.

Decreases runoff and erosion

What happens when it rains and there is nothing between rain drops and soil?

Rain hits soil really hard and causes some of it to wash away! Having cover crops between them cushions the force of rain drops and holds the soil in place.

Increases water infiltration

Similarly, having cover crops in the soil makes lots of little channels from where roots grow that rain can follow, making the soil hold more water than it could if roots weren’t there. The plants can also take up some of the water, so they’re really helpful in big storms for keeping water on-site.

Scavenges excess nutrients

Do plants take up all of the nutrients we give them?

No, most plants can only use about 60-70% of the nitrogen, for instance, given to them. What happens to the rest? It can leach into water – that’s a waste and a source of pollution. Some “catch crop” cover crops in particular are especially good at scavenging the leftover nutrients in soil to keep them in their biomass until the next crop needs them.
HOW DO COVER CROPS HELP SOIL?

**Adds nitrogen**

Who has heard of legumes? What is an example of a legume? Legumes are plants that have special relationships with specific soil bacteria called rhizobia. Rhizobia make little habitats on plant roots called nodules where they take nitrogen from the atmosphere that plants CAN’T use and turn it into plant-available nitrogen. Only legumes can do this. When rhizobia fix nitrogen, they trade it with plants for some of the plants carbon. When we put the legume plant material into the soil, it’s practically free nitrogen fertilizer.

**Controls weed**

Some cover crops like rye are really quick-growing and competitive, so they can outgrow weeds. When some cover crops grow big enough, we can keep them in place as mulch too, to keep weeds out while the main crops are growing.

**Adds organic matter**

All of the plant material both above and below ground is terrific for soil because it directly becomes soil organic matter!

HAVEN’T YOU USED COVER CROPS?

What has your experience been?
If you haven’t, why not?
Or why not more?
When we don’t know everything about how to use cover crop, it seems really risky to use them – and there are lots of real challenges, too! For instance, not all cover crop species are strong enough to survive through the winter here, and sometimes we don’t know when to plant and kill them. When it’s time to kill them, you might wonder what in the world you are going to do with all of the plant material, and then what if you don’t have the right equipment for the job? What if it doesn’t work and they spring back to compete with my main crops?

We made a big packet of information about all kinds of cover crops we can use here with information to answer some of these questions.

SELECTING A COVER CROP

There are a lot of cover crop options, so when you are trying to select which ones to use, it is important to have a goal. Do you want a lot of nitrogen? Do you have lots of extra nitrogen in the soil that you need to save – do you only have a lawn mower and need something a little smaller then? Make a goal. Then look at your timeline. When are the last of your main crops in the field you want to cover crop coming out? In the cover crops you’re choosing between, see what the latest planting date is. Do the same thing on the other end – what will you be planting in the spring, and will the cover crop be ready to be killed? Finally, do you have the right equipment for killing the cover crop? Some really big cover crops, like sorghum sudangrass, need a tractor to totally kill them. On the other hand, a low-lying clover can be killed with a lawn mower and rototiller.

ESTIMATING N CREDITS

One of the biggest uses of cover crops in terms of practicality is that they give us free nutrients. We are usually most interested in nitrogen, because our crops need so much of it. But how can we calculate how much nitrogen a cover crop has before we terminate it? That’s the last bit of what we will talk about for this unit.

In order to see how much nitrogen is on our cover crops, we need to follow these step-by-step directions.

1. How much plant material is in a given area?
2. How much nitrogen is in that material?
3. How quickly will the material decompose and become available?
4. Do you need extra nitrogen?
1. How Much Plant Material Is in a Given Area?

First, we want to know how much plant material is in a given space, right? So if we know how many feet are in an acre, we can sample just a foot of cover crops or so, right, and estimate from that how much is in the whole field. So you can take a ruler or meter stick to the field, make a square, and figure out how much plant matter is there. How? Lay they rulers on the ground, and collect all the plants in it from ground level and up. Put them in a paper bag and dry them at 140°F or so, until they are so dry that they are brittle or crunchy.

Then, think about how much area you sampled from. Say you did this twice in your field, and you used yardsticks to make a square. Each square is 9 ft², so you have 18 ft², right? Then, you need to know the dry weight of the plant matter you collected. Let’s pretend that these two samples together gave you 2.5 lbs. So how much biomass do you have per acre?

To get this number, you need to multiply the pounds per square foot that you have by the number of square feet in an acre. This gives us 2.5 pounds of material per 18 square feet times 43,560 square feet in an acre. What does that give us? So in one acre, we have approximately 6,050 pounds of aboveground plant biomass. That’s a lot! But how much of it is nitrogen...?
2. HOW MUCH NITROGEN IS IN THAT MATERIAL?

The amount of nitrogen in a plant depends on two main things: what kind of plant it is, and how mature it is.

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<th>COVER CROP</th>
<th>EXAMPLES</th>
<th>%N</th>
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<tr>
<td>Legumes</td>
<td>Hairy vetch</td>
<td>4% at flowering</td>
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<tr>
<td></td>
<td>Clovers</td>
<td>3% is seeds are maturing</td>
</tr>
<tr>
<td></td>
<td>Pea</td>
<td>4% at flowering</td>
</tr>
<tr>
<td></td>
<td>Sunn hemp</td>
<td>3% is seeds are maturing</td>
</tr>
<tr>
<td>Non-legume grasses</td>
<td>Rye</td>
<td>3% at flowering</td>
</tr>
<tr>
<td></td>
<td>Oat</td>
<td>2% is seeds are maturing</td>
</tr>
<tr>
<td></td>
<td>Sorghum</td>
<td>Similar or a little less than grasses</td>
</tr>
<tr>
<td></td>
<td>sudangrass</td>
<td></td>
</tr>
<tr>
<td>Non-legume broad-leaves</td>
<td>Buckwheat</td>
<td>3% at flowering</td>
</tr>
<tr>
<td></td>
<td>Tillage radish</td>
<td>2% is seeds are maturing</td>
</tr>
<tr>
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<td>Canola</td>
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Plants have the most nitrogen in them right before they make seeds, so right about when they’re flowering. When they make seeds, they take most of the nitrogen in their tissues, so the green parts, and shoot them into the seeds. That’s why bean plants turn brown after they make beans, and why peas and beans are so high in protein - because protein is made of nitrogen! Legumes have the most nitrogen, but you can see that non-legumes have nitrogen in them too – just less.

So how much of our 6,050 lbs of biomass is actually nitrogen? Well let’s say that the cover crop was red clover and it was flowering. So it should have the most nitrogen it’s going to have in its lifecycle, about 4%. We just have to multiply 4% by the total amount of biomass, and then we have lbs of nitrogen per acre. What do you all get for this number? More than 200 pounds of nitrogen! But we aren’t done yet...

3. HOW QUICKLY WILL THE MATERIAL DECOMPOSE AND BECOME AVAILABLE?

Remember, it’s not all available to plants yet! Microbes have to eat it first to convert it into a form that plants can use. How quickly this will happen depends on one major thing: whether or not you till in the cover crop residue. If you leave it on the soil about 40% of it will be decomposed over the course of the year. How much is that total? Almost 100 lbs! It’s a lot. If we till it in, we will get even more though, about 50%, in the first year.

Why do you think that is?

Yes, because then soil microbes have better access to it. If we till it in, how much nitrogen do we get in the first year?

121 pounds!
4. DO YOU NEED EXTRA NITROGEN?

What are you planting now?

Cabbage removes approx. 220 lb N/ac

will need 220 – 121 = 99 more lb N if we tilled in the clover

WHAT NOW?

Use manure, compost, or fertilizer; or, rely on accumulated soil organic N from all the organic matter you have been adding!

Finally, let’s assume you will till the clover in. Is that enough nitrogen though, or do you need more for your crop? You need to know what you’re planting and then have an estimate for how much nitrogen in needs in total.

I am pretending that we will plant cabbage, and I found on the internet that an acre of cabbage removes about 220 lb of nitrogen. What now? You need nearly 100 more pounds of nitrogen. You can use compost, manure, or fertilizer. But you also want to remember that if you have been building soil organic matter, some of the accumulated nitrogen will also be mineralized and made available for plants.

What questions do you have about estimating the amount of nitrogen we can give plants with cover crops?

CHAPTER 3 RESOURCES

- Albert Lea Seed
- Midwest Cover Crop Council
  www.mccc.msu.edu/CCinfo/cropbycrop.html
- SARE Cover Crop Fact Sheets
- Cover Crop Comparison Chart
- Cover Crop N Contribution Calculation Worksheet
Let’s first step back and think about what nutrients plants need, where they come from, how we provide them if they aren’t already in the soil, and how they help plants grow. Then we’ll talk about how soil organic matter feeds plants, and how to test soil for its nutrients.
WHERE DOES IT COME FROM?

PLANTS

Plants grow through photosynthesis, which uses:
- sunlight
- CO₂ from the air
- water
to make carbon-based plant matter.

The first big question is, “How do plants grow?” - and for all plants, the answer is that they use a process called photosynthesis. Photosynthesis is how plants take carbon dioxide (CO₂), which there's a lot of in the air, and turns it into organic, or living, plant material. Plant scientists usually call this converted carbon carbohydrates or photosynthates. In order to photosynthesize, plants need sunlight, carbon dioxide, and water.

CARBON (C)

Plants make their own carbohydrates, but not all living things do. Do humans use photosynthesis? No, we eat carbon-based materials. We eat fruits and vegetables and grains, that grow using photosynthesis, and we eat food from animals who also eat plants. So carbon, even though it's the main nutrient we consider when we think about soil organic matter, is not a limiting nutrient for plants. We don't need to worry about giving plants enough carbon. We care about SOM, which is formed mostly by carbon, because of environmental reasons and because SOM holds other nutrients for plants.

NITROGEN (N)

Organic (carbon-based) OR Inorganic (not carbon-based)

Organic N needs to be turned into nitrate (NO₃⁻) or ammonium (NH₄⁺), which is called “mineralized”, by soil microorganisms before plants can use it.

These are “made available” over time as microbes mineralize them, not all at once like fertilizers.

Next, let’s think about where nitrogen comes from. There are two main forms of nitrogen that go into soil to feed plants. The first form, organic sources of N, are what we’ve been talking about. These are sources that come from organic, or living, things, and includes cover crops, manure, and compost. The other main form of N inputs is inorganic sources. Inorganic sources are also called synthetic, because they are NOT directly made from living things. These are what we think of as commercial fertilizers: urea, anhydrous ammonia, ammonium nitrate, etc. These inorganic sources are already in forms that plants can use. Organic sources, on the other hand, are more complicated.

Organic nitrogen sources need to be “mineralized” by microbes in the soil before plants can use them. This is when microbes turn organic sources into inorganic products, like nitrate and ammonium. This doesn’t happen all at once, which is good because plants use nitrogen over time, not all at once. If it was all made available at once, a lot of it might be lost to other plants like weeds, or washed through soil into bodies of water.
Phosphorus is another element that is essential for plants to grow, but it comes from sources that are a little different from nitrogen. Some phosphorus can be provided from organic materials - manure, in particular, provides a lot of P (so we have to be careful when we apply it because it can pollute water when there is too much!). Mineral rocks contain a lot of phosphorus also, which become part of soil when it gets weathered away. Finally, inorganic phosphorus exists through commercial fertilizers also.

Plants can only take up inorganic and soluble P.

Like N, microbes mineralize P over time from organic sources.

Sort of like how plants can only use inorganic forms of nitrogen, they can also only use inorganic forms of phosphorus that is in the soil water, which is what soluble means. Microbes mineralize P similar to how they mineralize N, from organic sources. If we were to apply manure to a field, microbes would mineralize both N and P from it.

Potassium is a lot like phosphorus. It also comes from organic and mineral sources, although P and K are somewhat specific to certain rocks. Commercial K fertilizers are also available.

**Plants can only take up K ions (K⁺).**

K⁺ adheres to SOM, which keeps it from leaching and helps some of it stay available to plants.

Like N and P, plants can only use the simple, inorganic form of potassium, which is K⁺. It sticks really well to individual soil particles and also to SOM, which keep it from going into bodies of water. N and P are usually more limiting for plant growth than K.
The funny thing about mineralization is that microbes need really specific amounts of elements, which is most important when it comes to nitrogen. Let’s pretend that these brown dots are carbon, and the green dot is nitrogen.

For every 25 or less parts of carbon that a microbe consumes, it need also one part of nitrogen.

But sometimes, there isn’t enough nitrogen. There are about 50 parts carbon here, but only one part nitrogen. But how many parts nitrogen does the microbe need if it wants to eat all the carbon? Two!

There is no extra N, so the microbes hoard what they get in their bodies rather than putting it back into the soil. That’s why putting high-carbon material in soil, like straw or other woody materials, we often see a nitrogen deficiency - the microbes are hogging all the nitrogen! That’s what we call immobilization.

However, when they eat materials relatively high in nitrogen (which is what you might hear called “low C-to-N ratio” material), they put the extra N back into soil, but mineralized. Then plants can use it.

Overall, when it comes to adding material to your soil, adding a high nitrogen material like alfalfa is much better at providing nitrogen to plants than lower N materials like straw. Remember, green things are usually higher in N than brown things, because N-based chlorophyll makes plants green!
Nutrient Management

Soil Health & Nutrient Management for Immigrant Farmers

HOW DO I SOIL SAMPLE?

There is a lot more to soil than meets the eye! If you are thinking about adding nutrients to soil, it’s a good idea to find out what’s already in the soil and to fill the gap from there. This way, you won’t waste money on buying unnecessary fertilizers. So in order to know what’s in your soil, it needs to be sampled from your field and sent to a testing lab. Sampling the soil is easy, but there are a few guidelines. You can collect multiple samples, which is good for if you are farming multiple locations. And each sample should be made up of about ten composites, which means cores or spade-fulls. Composites are combined to make one full sample. Make sure to get soil surface litter out of the way before soil sampling. Usually, it is a good idea to collect samples from about 6 inches deep in the soil, or as deeply as you till, because tillage incorporates nutrient sources and activates microbes.

SOIL TESTING

- You can submit multiple samples
- Many “composites” make up one sample – for instance, take 10 soil cores and combine them in a bucket, and submit the total
- Take representative samples (only composite soil from uniform areas)
- Don’t include surface plant material
- Sample as deeply as you till (usually 6-8” deep)
- The more variable your landscape (hilly, different crop rotations, different soil types, etc.), the more composites you should take!

But remember to balance! If compost is overwhelmed with carbon, then the nitrogen will become immobilized. It is also possible to add too much green material, which you’ll know if your compost is too wet and smells bad. Crops only need so much nitrogen – after a certain point, they can’t use anymore. Sometimes, they can even suffer from too much nitrogen. For instance, many nightshades will become big and bushy but not produce fruit, or will set fruit late.

Balance is key!
Then, where should you send your samples to be tested? If you live in or near the Twin Cities, the UMN Soil Testing Lab is a good option. They have a good website with all the information you need to know about how to collect soil samples, and how to ship them or drop them off. It might seem a little expensive, but having soil tested might end up saving you lots of money on fertilizers! Do note that nitrogen is not provided in a normal soil test report, but that it can be inferred from organic matter measures. We will talk about how to do this in a couple minutes.

The U asks folks who submit samples to fill out this form, and other places likely have similar forms. Make sure that you name the sample in such a way that is not only unique, but that you can identify and match to a location later on. Let the U know what county you’re farming in, because then they can look up your soil type. Also provide the history of the field you’ve sampled. What have you planted there recently? This is important for them to know how much nitrogen, especially, to recommend later. If you planted a legume recently, they will factor the nitrogen from it in! Tell them what you will plant, so they know what your soil nutrient needs are, and what kind of test you’d like. Usually, a “regular” test will provide more than enough information.

WHERE DO I SEND SOIL SAMPLES?

The University of Minnesota has a Soil Testing Laboratory!

- Drop off samples at the Crops Research Building, rm 135 (1902 Dudley Ave, St. Paul MN 55108)
- They have a great website: soiltest.cfans.umn.edu
- A normal soil report costs $15 per sample.
- However, plant available nitrogen can be estimated from other values on the soil test report.
- When you drop off the samples, you will be asked to fill out the following form...
Here is an example of what a soil test report looks like. Again the really important parts are highlighted. How much organic matter is there? 3%, which is pretty good. It tells us the acidity, which is the “pH”. And finally it tells us the nutrients. Like we talked about, what we said we wanted to plant! So let’s look at the middle crop, cabbage. How much nitrogen does it need? 180 pounds per acre – that’s a lot! But we know they didn’t include soil N in that amount.

Here’s how we can figure that out on our own... We can calculate the amount of nitrogen that will be made available to plants over the course of the growing season by looking at the %SOM. Remember, before applying new nutrients, it’s a good idea to take into account what the soil already contains, and what you’ve added in terms of cover crop nutrients and other organic sources. Subtract those from what your soil test recommendations say in order to save money and not waste nutrients.

So what if you want to know how much nitrogen you have, but you don’t want to pay (and wait) for nitrate measurements? We can do the math!

- All the soil in the top 6 inches of an acre weighs about 2,000,000 pounds.
- If we have 3% SOM, like in the report, that means we have $0.03 \times 2,000,000 = 60,000 \text{ lb/acre}$ of SOM
- But SOM is only about 7% nitrogen...
- So in the soil, about $60,000 \times 0.07 = 4,200$ lbs of nitrogen exist as SOM (org N)
- BUT, finally, only about 2% of this is mineralized annually...
- $4,200 \times 0.02 = 84 \text{ lb mineral N per acre (quite a lot!)}$

Here’s how we can figure that out...
CHAPTER 4 RESOURCES
• Soil Sampling Guideline (www.extension.umn.edu)
• Calculating Mineralizable Soil N
• Nutrient Deficiency Symptom Library for Horticultural Crops

CHAPTER 5 RESOURCES
• N Cover Crops on the Intensive Market Farm
• Spring Rose Growers Co-op YouTube Channel
• Farm Hack (website with ideas for DIY farm tools!)

REFERENCES

Sustainable Farming Association (SFA)
• http://www.sfa-mn.org/beginning-farmer-resources/
• http://www.sfa-mn.org/resources/producers-marketers/

Natural Resource Conservation Service (USDA-NRCS)
• http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/plantmaterials/technical/publications/?cid=stelprdb1077238
• http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/edu/
• http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/assessment/?cid=ncrs142p2_053870

MN Department of Agriculture (MDA)
• http://www.mda.state.mn.us/protecting/sustainable/mfo/beginningfarmer
TEACHING STRATEGIES

- **Think-Pair-Share**: In Monday’s introduction, you reflected on the questions provided about cover crops and soil health, traded reflections with your neighbor, and then shared that information with everyone. [http://www.readingrockets.org/strategies/think-pair-share](http://www.readingrockets.org/strategies/think-pair-share)

- **Brainstorming + Flip Chart**: In Monday’s unit on Soil Basics, you brainstormed what sorts of things might fall into soil physical, chemical, and biological properties and separated the parts into a flipchart that you can use to organize your knowledge and create your own lecture. [http://www.crlt.umich.edu/tstrategies/tscbt](http://www.crlt.umich.edu/tstrategies/tscbt)

- **Case-Based Learning**: At the end of Monday, we used your farming operations as examples of how and when to make cover crop decisions. [http://www.crlt.umich.edu/tstrategies/tscbt](http://www.crlt.umich.edu/tstrategies/tscbt)

- **Muddiest Point**: At the end of Monday, you reflected on what you learned that is still most muddy, or unclear - making it easier to think more consciously about the next day and also for us to be sure to clear up [https://cft.vanderbilt.edu/guides-sub-pages/cats/](https://cft.vanderbilt.edu/guides-sub-pages/cats/)

- **Parking Lot**: On Tuesday, we asked you to make individual post-its for what you had learned, what you plan to use, what we call “Aha! Moments”, and what questions you still have. [http://www.competencyworks.org/how-to/creating-a-classroom-parking-lot/](http://www.competencyworks.org/how-to/creating-a-classroom-parking-lot/)

- **Affinity Chart**: After everyone posted their notes in the parking lot, we took it one step further to create an affinity chart - we grouped similar ideas together in order to see where everyone’s ideas were similar and/or diverged, helping us see what needs clarification and how our teaching was received. [https://www.mindtools.com/pages/article/newTMC_86.htm](https://www.mindtools.com/pages/article/newTMC_86.htm)

- **Peer Instruction**: Tuesday morning, you taught UMN students about what you learned the day before regarding soil health and cover crops. [https://library.gwu.edu/utlc/teaching/peer-instruction](https://library.gwu.edu/utlc/teaching/peer-instruction)