Virginia Cooperative Extension

Virginia Tech • Virginia State University

Basic Soils

Amy Byington

Lee County-VCE

afannon@vt.edu

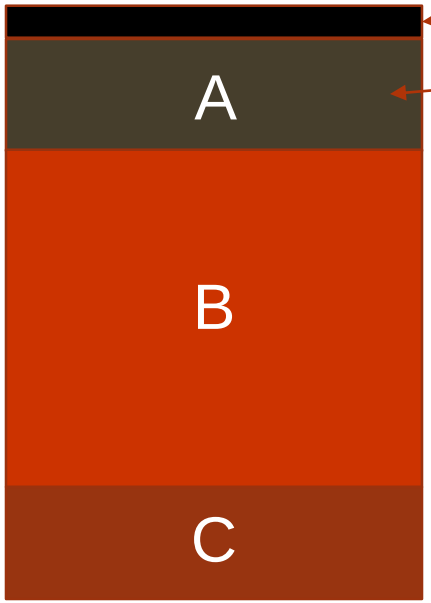
276-546-2057

Objectives

- To understand basic characteristics of soils that make up soil quality.
- To understand how to properly take a soil sample.
- To understand how to interpret and the concepts of soil testing reports.
- To understand importance of soil fertility.
- To understand various ways to amend soils to increase soil quality and fertility.

Soil Profile

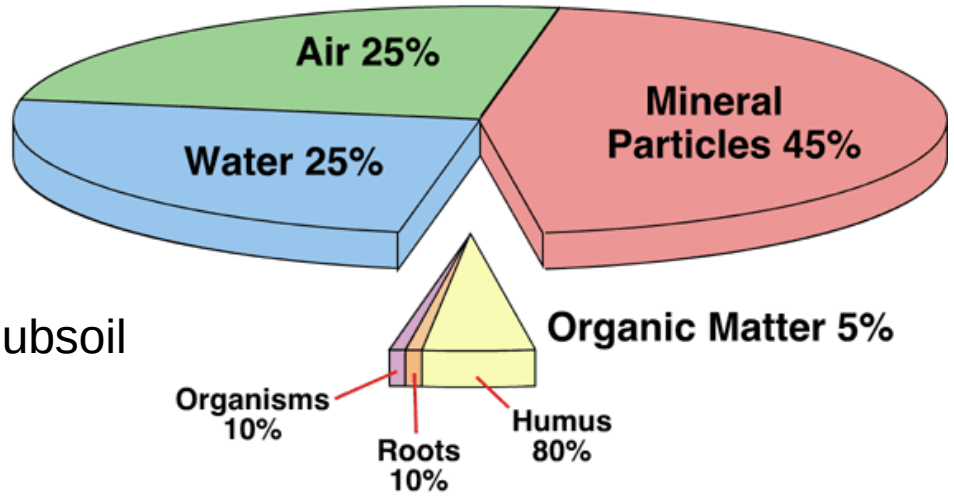
Soil Horizons



O- organic matter

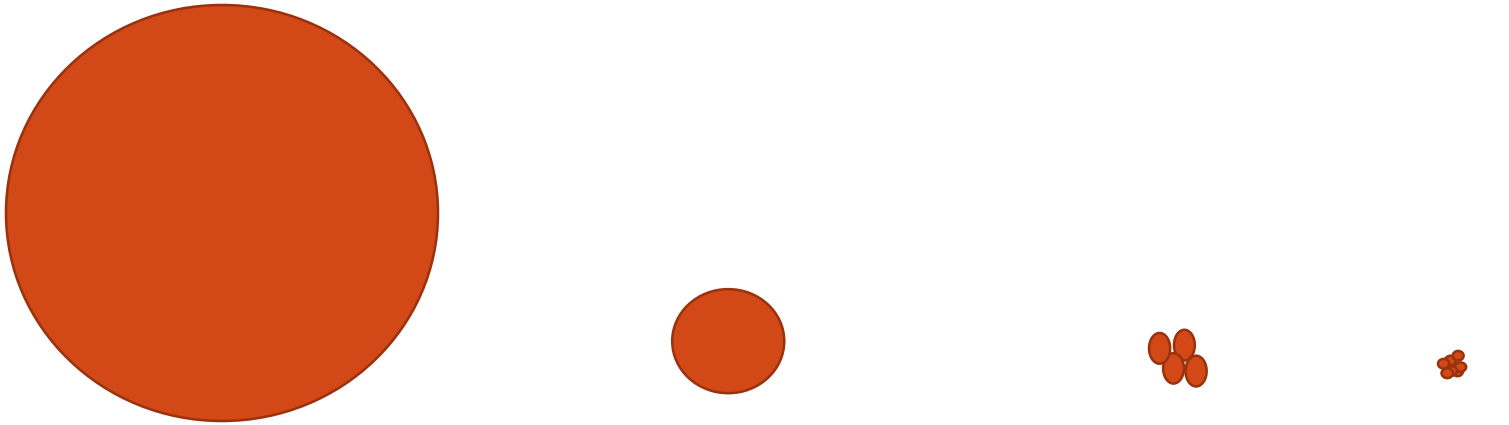
A- topsoil

B & C- subsoil



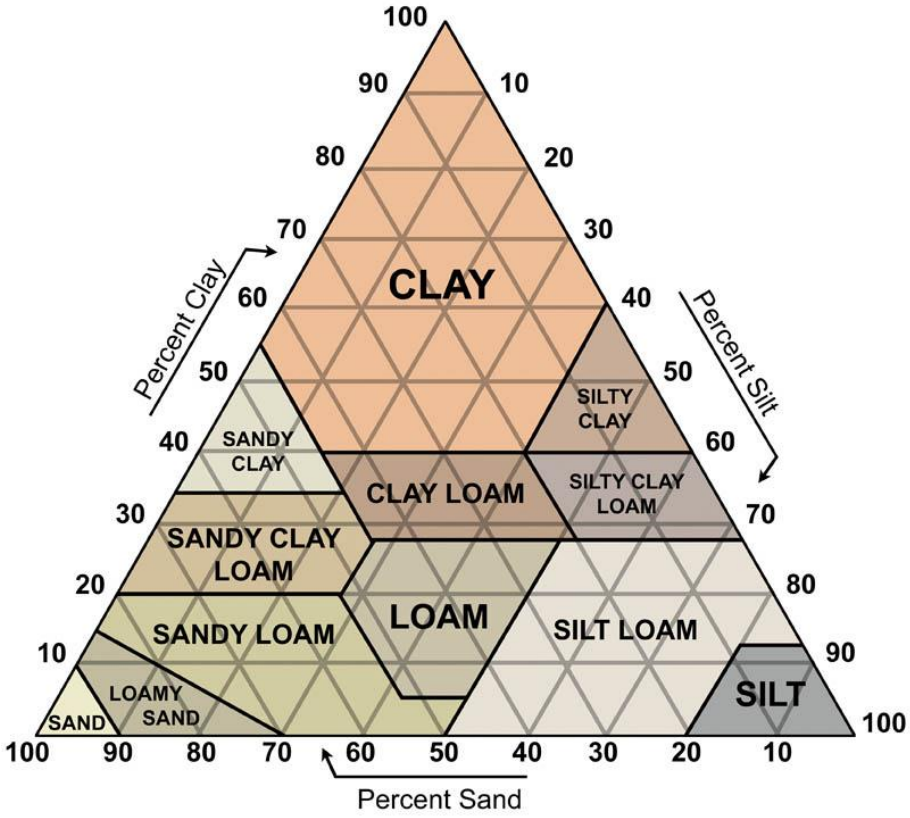
Soil Particles

- Gravel- (4.75-75 mm)
- Sand- (0.075-4.75 mm)
- Silt- (0.002-0.075 mm)
- Clay- (<0.002 mm)



Soil Characteristics

- **Soil texture** is the foundation for soil characteristics and relates to water movement, water availability, nutrients in soil, and soil structure predominantly.
- **Soil texture** is determine by the amount of sand, silt, and clay present using a texture triangle.



http://www.soilsensor.com/images/soiltriangle_large.jpg

Soil Characteristics

- **Infiltration** is the movement of water into the soil such as when it rains.
- **Percolation** is the movement of water within the soil or when the water down through the soil.
- **Available water** is the water that is actually available to plants. Not all water in the soil can be taken up by plants. Depends greatly on soil texture.

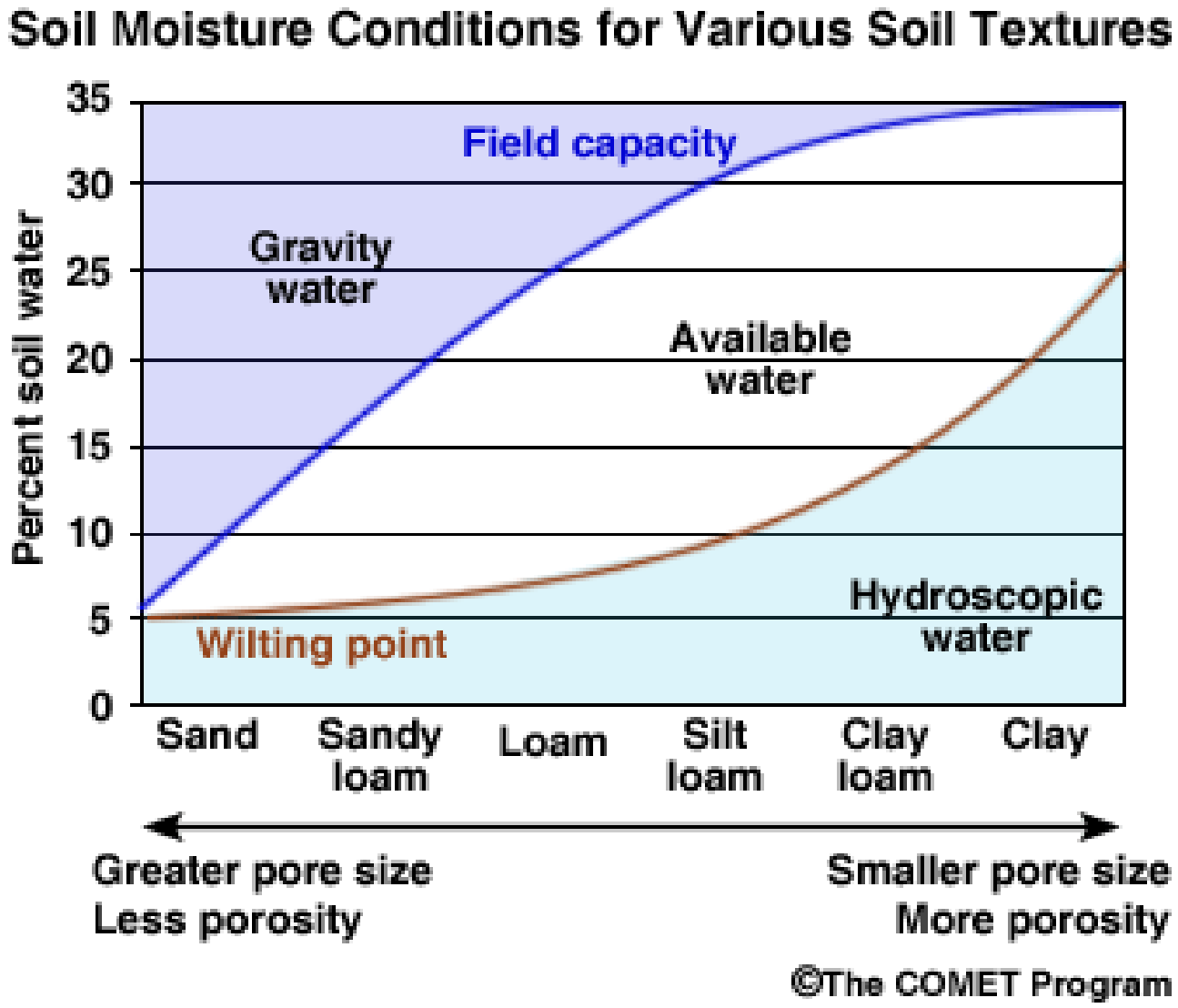
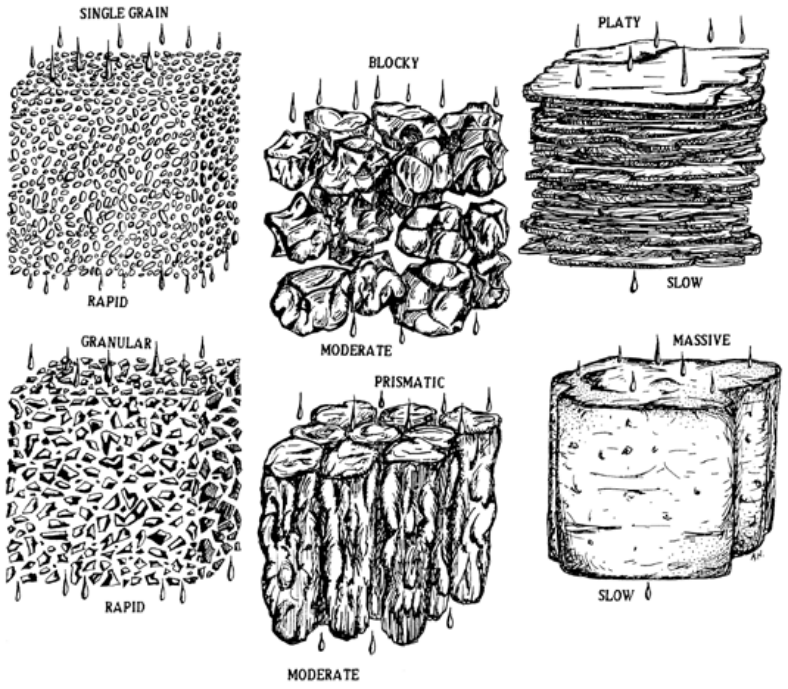


Figure 2. Soil moisture conditions for various soil textures.
Ref: The COMET program, University Corporation of atmospheric research
https://blog-crop-news.extension.umn.edu/2019/01/soil-water-basics-for-irrigation.html

Soil Characteristics

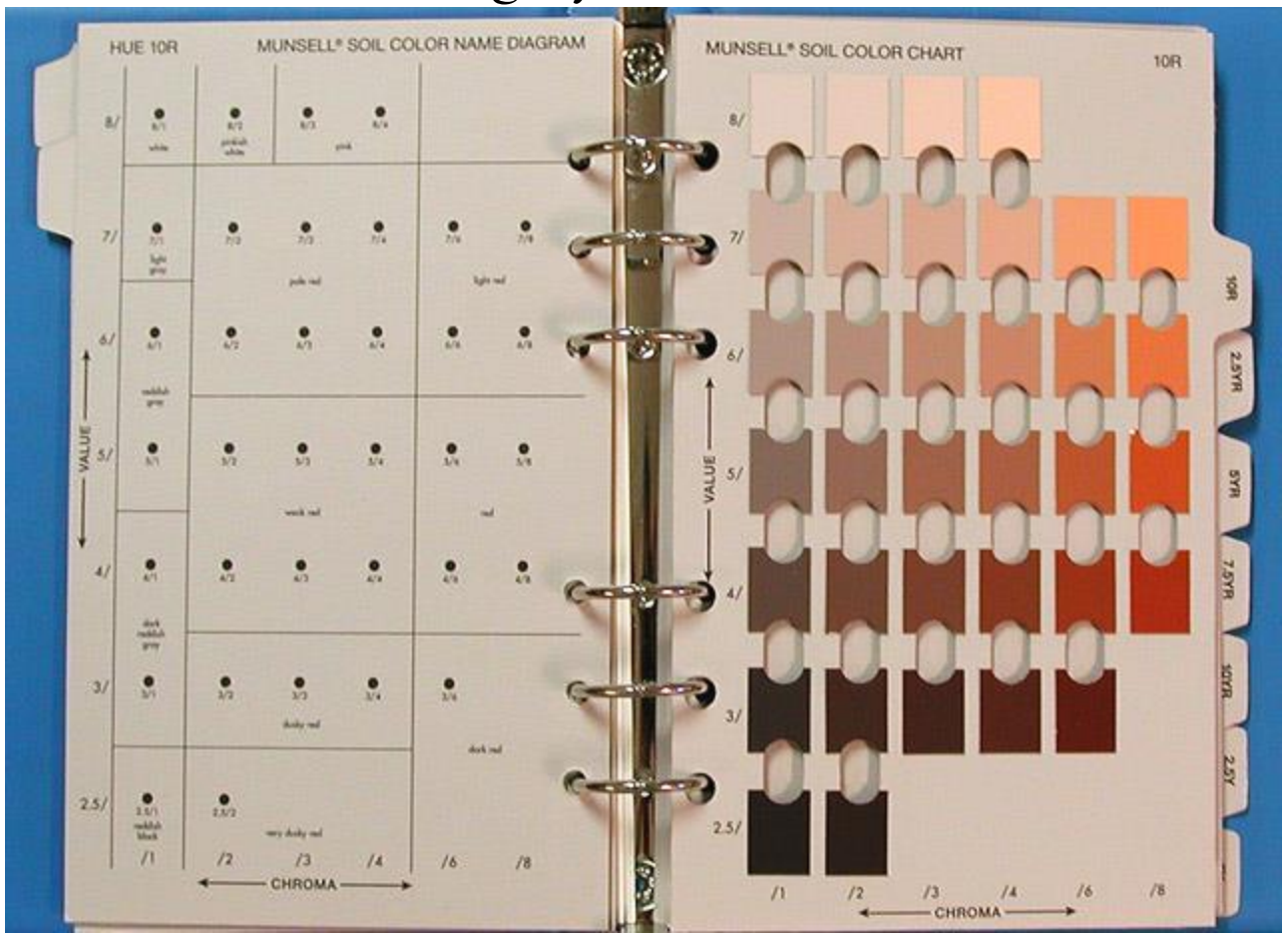
- **Soil structure** relates to how your soil will allow water movement and root movement and stability of the soil.



http://cru.cahe.wsu.edu/CEPublications/eb1633/fig3.gif

Soil Color

- Soil color can give us clues to what is going on in a soil.
- Natural color of soil is grey!

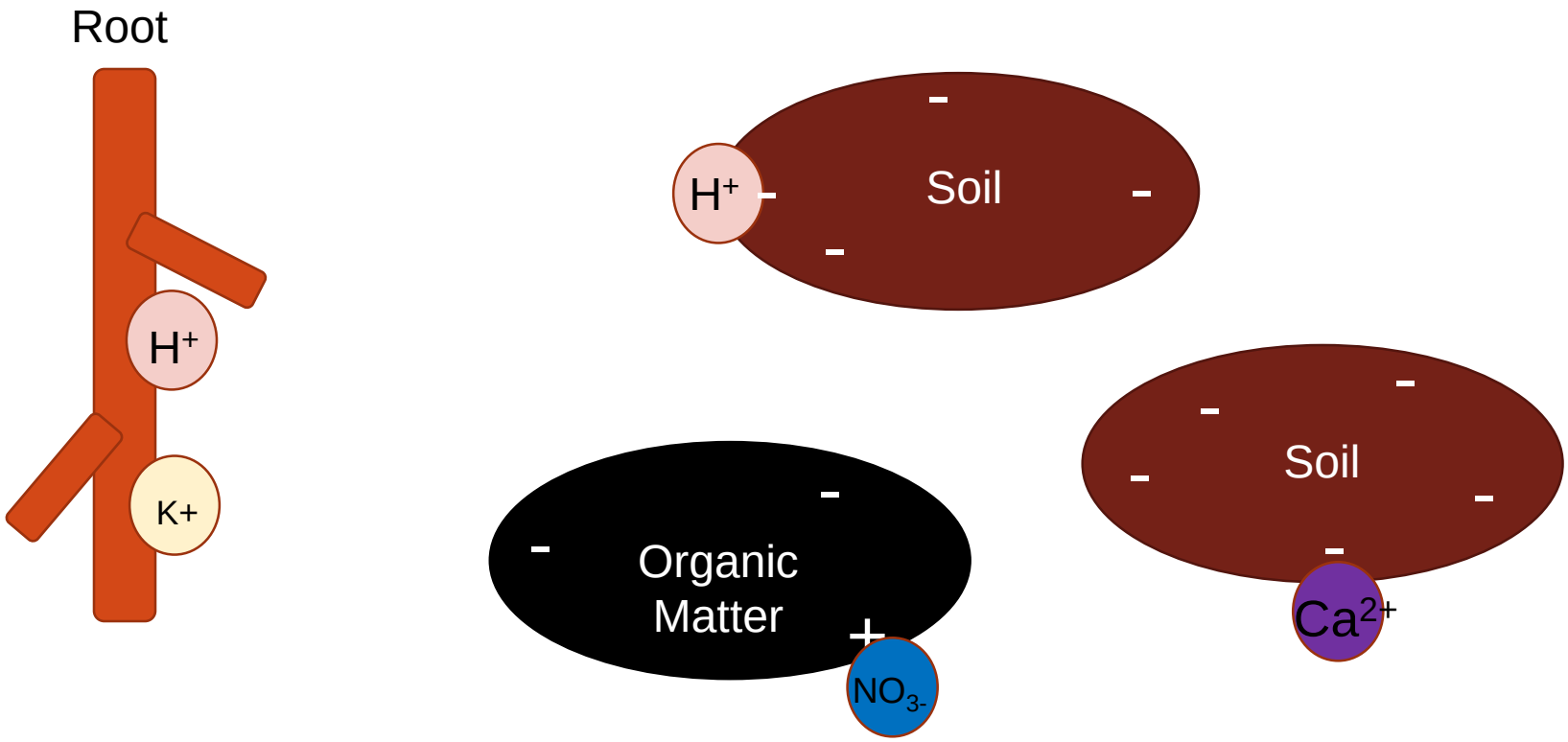


Soil Health

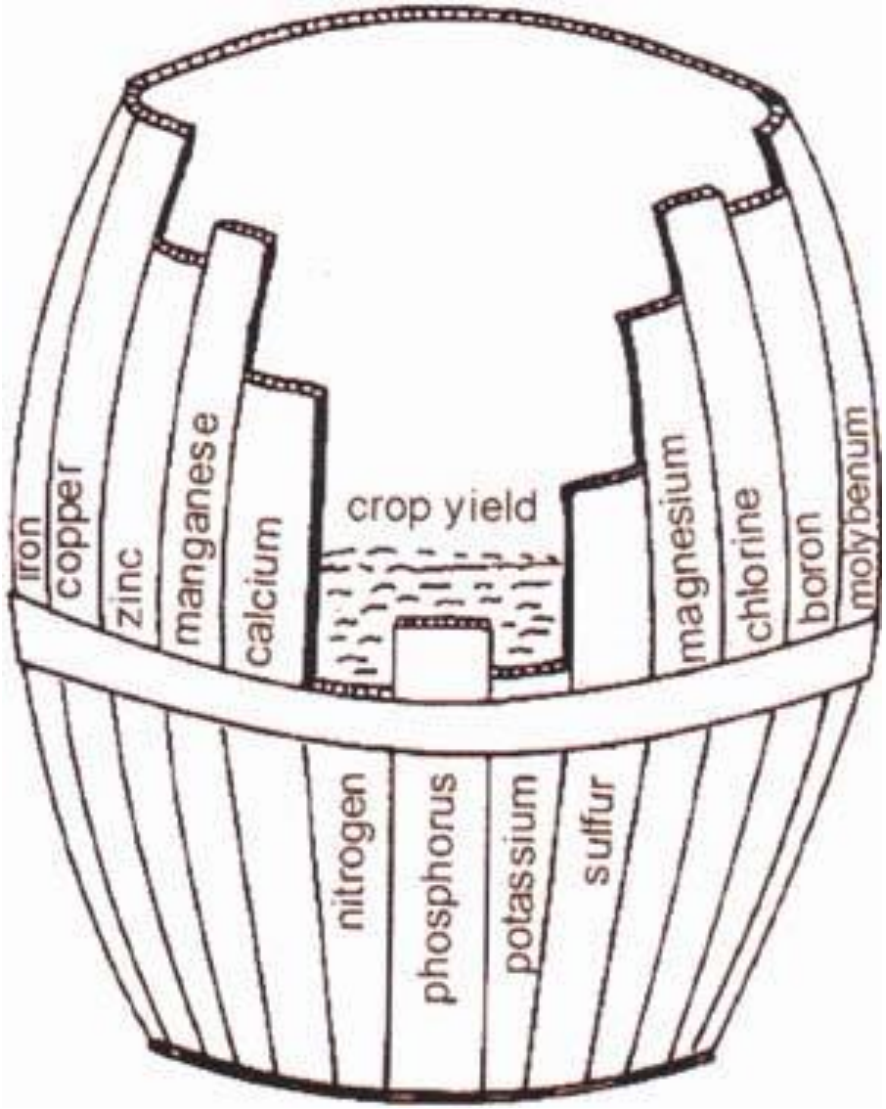
- Enhance organic matter
- Avoid excessive tillage
- Manage pests and nutrients efficiently
- Prevent soil compaction
- Keep the ground covered
- Diversify cropping systems

http://soils.usda.gov/SQI/concepts/soil_organic_matter/som.html

Soil is Chemistry!!!



- Soil nutrients and particles have charge of either Cations^{+} or Anions $^{-}$
  - Depending on their $^{+}$ or $^{-}$ some nutrients can be bound and not available to the plants



http://www.fao.org/docrep/008/ae939e/ae939e1l.jpg

Macro-Nutrients

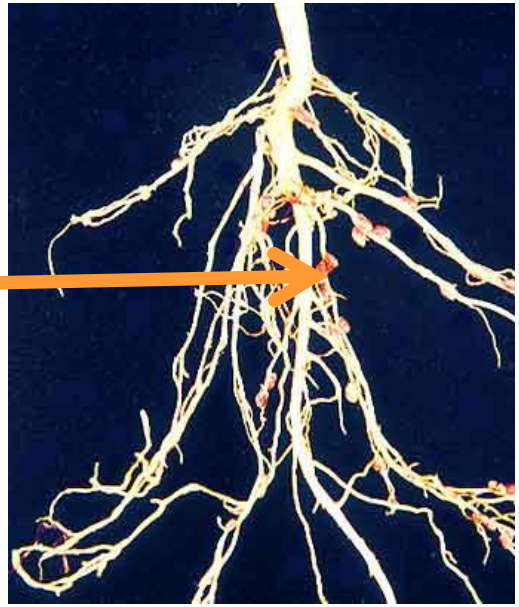
- Nitrogen- Very water soluble and mobile throughout the soil. There are several loss pathways (denitrification, voltization, leaching, & erosion) making it the most limiting nutrient.
- Phosphorus- Does not readily leach from soil; however, it can end up as a pollutant in streams and rivers due to erosion. It can be made unavailable due to too much Fe & Al in low pH and Ca in high pH.
- Potassium- Not readily lost from the soil. Most potassium in soil comes from the rock parent material and often is not in mobile form.

Legumes

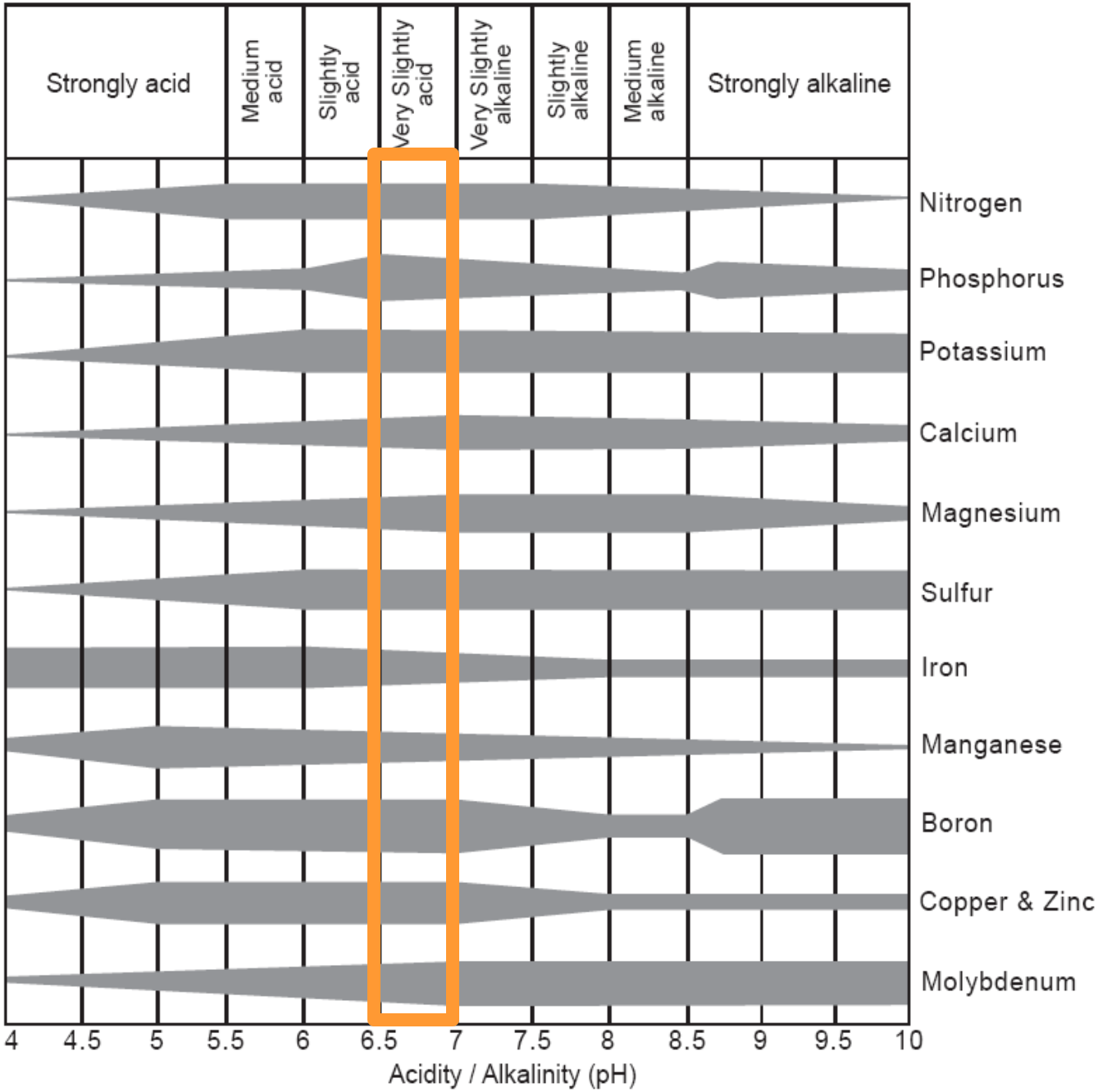
Legumes interseeded with grass or small grains				
Good conditions, adequate water, P, K, and pH	Alfalfa, Clover[2], Vetch, Hop Clover, Ladino clover, Annual Lespedeza	Scattered (1 legume plant/yd[2])	100	1 to 5[3]
	Hop Clover, Annual Lespedeza	Thick stand, 1 ft. tall	1,000	15 to 30[3]
	Alfalfa, Clovers[2]	1 legume plant/ft[2], 12 to 15 in. tall	1,000	20 to 30[3]
	Alfalfa, Clovers[2]	1 legume plant/ft[2], 15 to 24 in. tall,	1,500	30 to 60[3]
	Clovers[2], Vetch	Thick stand, 3 legume plants/ft[2], 20 to 30 in. tall	2,000	40 to 60[3]

[3] Additional N from roots that will eventually become available may be estimated at as little as10 lb N/acre for short-lived annuals to 90 lb N/acre for perennials with well developed root systems.

Nodules on red clover- Make sure to inoculate your legumes with the specific *Rhizobium* for that plant.



https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y



https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y

Lime and pH

- pH determines what nutrients are available by using lime you can alter this pH up, but if you want to go down you will need to use elemental sulfur.
- Crops are specific to pH example:
  - Blueberries like pH in the 4 or 5 range if it gets too high they get an iron deficiencies.
  - Corn prefers a pH in the 6 range.
  - Most grasses and legumes prefer 5.5-7.
- Lime is your cheapest fertilizer!!! Good investment!! Can get straight from quarry ask for AG Lime.
- Also, normally is dolomite lime and supplements your Mg and always supplements your Ca.
- Lime couple months (3) ahead of planting to get the pH and time for reaction to occur. Take a soil sample before planting to check level of pH after liming is always a good idea.

Why take a soil test?

- Reduce costs of fertilizer
- Reduce overuse of fertilizer
- Improve management of soil
- Improve plant health and production
- Decrease environmental issues such as pollution
- Basic soil testing is **free** to producers and fairly cheap for homeowners at $10 a sample!!!!

What does a soil test from Virginia Tech check for?

- Phosphorus
- Potassium
- Magnesium
- Calcium
- Zinc
- Manganese
- Boron
- Copper
- pH
- Reserve Acidity
- Soluble Salts (extra charge)
- Organic Matter (extra charge)

How to take a soil test?

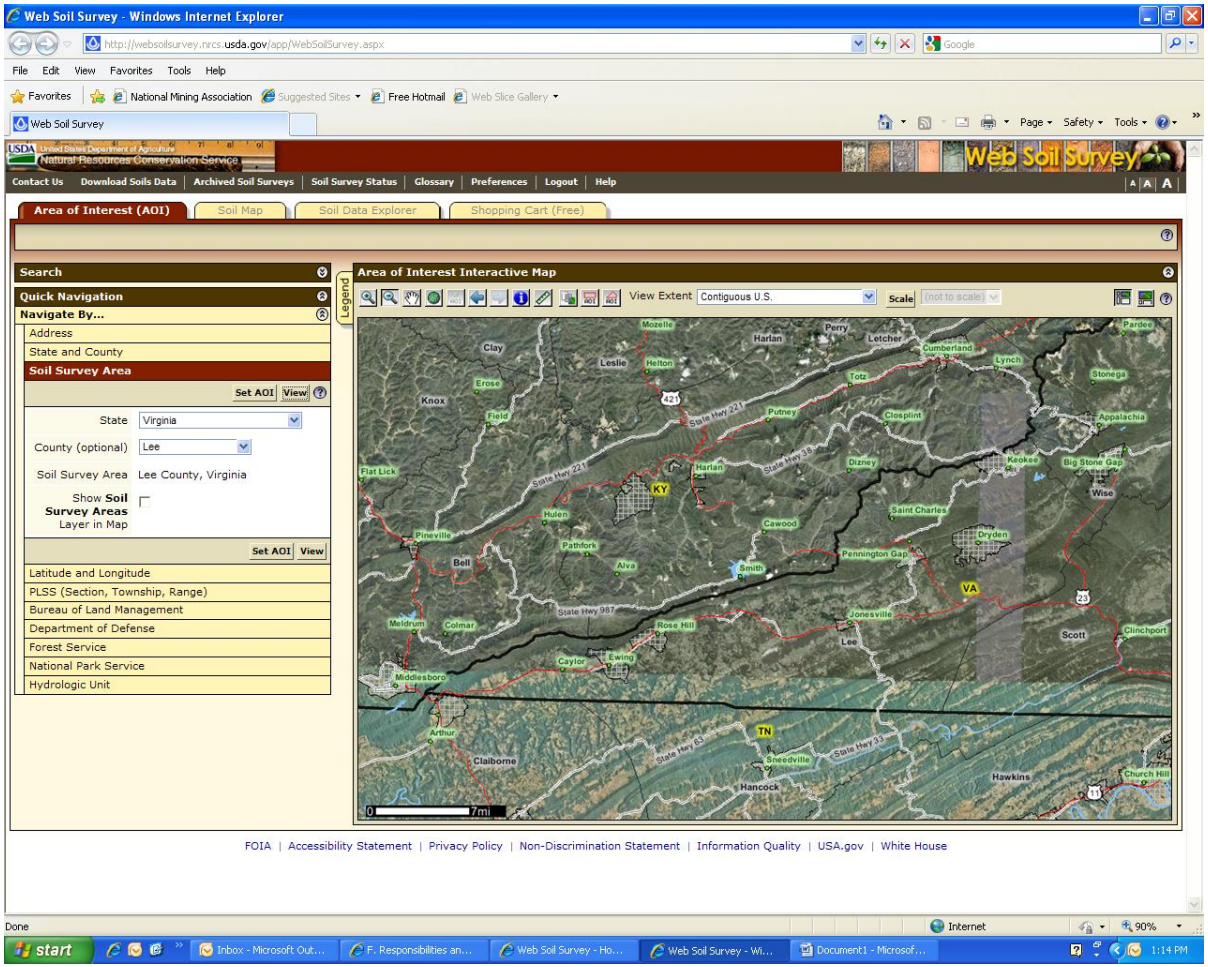
1. Divide area to be sampled based on practices used and production.

- Try to sample over a general area and make specific samplings for trouble areas.
- Try to use a map to mark where sampling.

Questions to ask yourself:

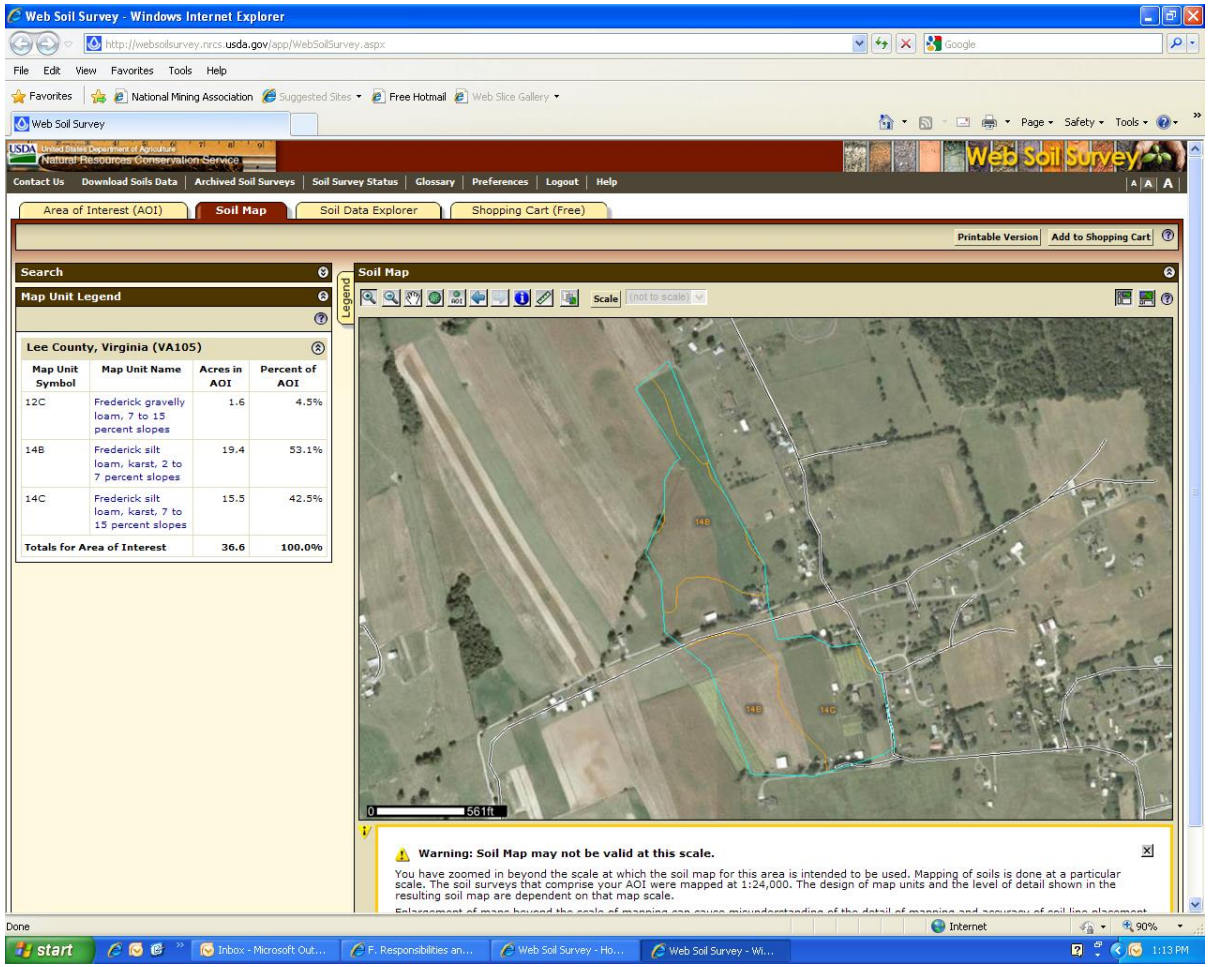
- Did I do anything different to this area than another?
- Has this area had better yields?
- Is there a natural divide such as slope or drainage?
- Does the soil appear differently on this side of the field then the other?
- What crops will be going here as different crops and grasses have different levels of nutrients required?

Web Soil Survey



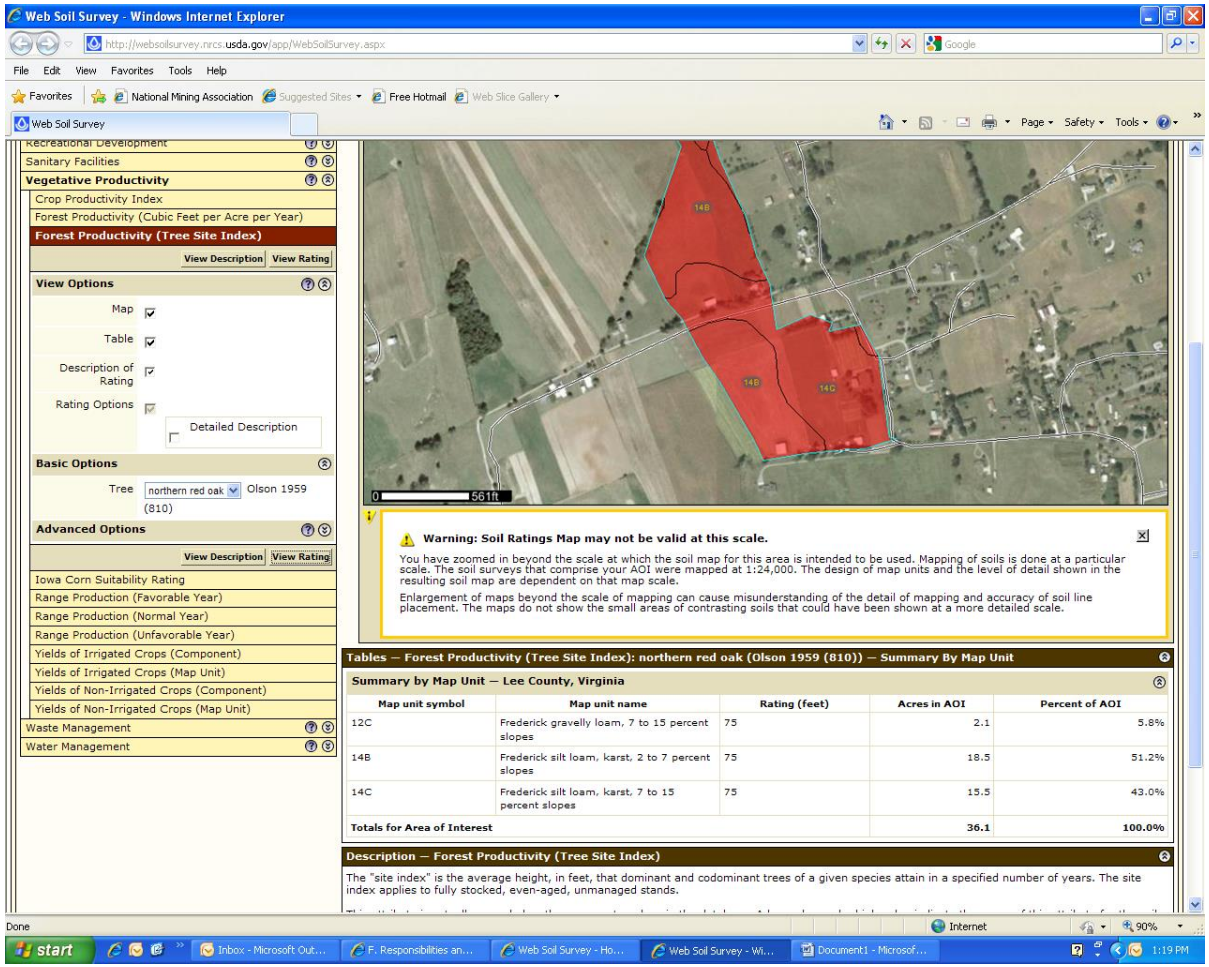
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Web Soil Survey



http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Web Soil Survey



http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

How to take a soil test?

2. Use proper tools to take samples.

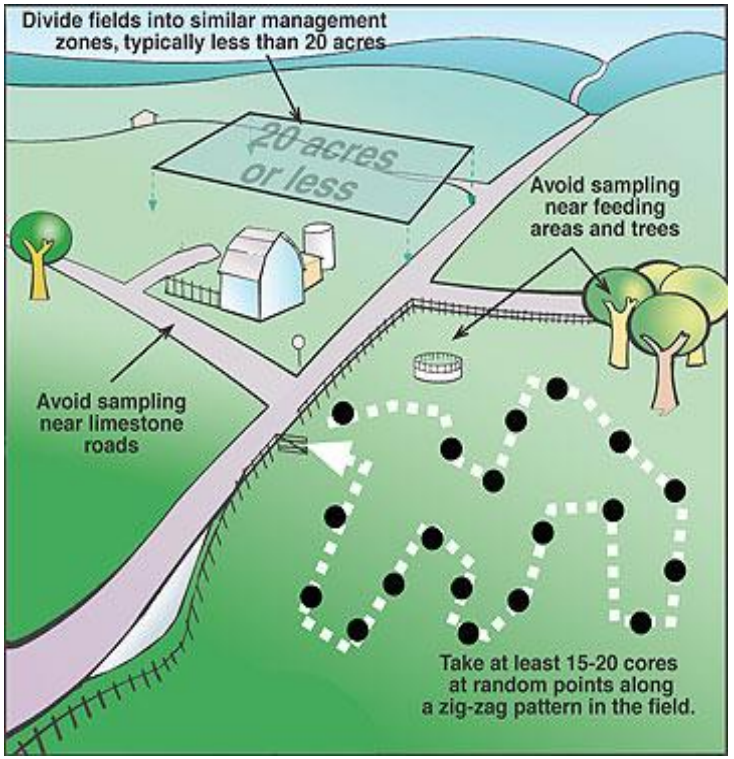
- Soil augers and tubes are wonderful tools, but spades and shovels work just as well. However, make sure to take the whole soil and not just the surface (1”).
- Make sure you take a sample that has equal parts of the surface and the lower portion needed for a sample.
- Use a clean bucket to mix the soil together.

http://pubs.ext.vt.edu/452/452-129/452-129.pdf

How to take a soil test?

3.Take a good sample of soil!!

- Try to take at least 1-2 subsamples per acre such as a 20 acre field would have 15-20 subsamples.
- Take the samples to a depth of 6-8" if the soil as been tilled or plowed and 2-4" for pasture or lawns.
- Sample pastures every 3-5 years, hay field 1-3 years, and crop fields every year.
- Avoid taking a sample from unusual places such as old fence rows, old roadbeds, eroded spots, where lime or manure has been piled, or in the fertilizer band of row crops.
- Try to take the samples randomly or in a zigzag manner.



http://pubs.ext.vt.edu/452/452-129/452-129.pdf

How to take a soil test?

4. Mix the sub-samples soil of soil completely before making one final composite soil sample. Complete all paperwork.

- Pick out all plant and foreign material from the soil sample
- Fill out the sampling sheets for each sample as complete as possible. The more knowledge the testing lab has the better the recommendations will be provided.
- Mark the boxes with proper names and write down for your records name of sample and where sampled.
- Mail the boxes and sampling sheets to Soil Testing Laboratory, Department of Crop & Soil Environmental Sciences (0465), Virginia Tech, Blacksburg, VA 24061. Please allow for around 2-4 weeks for results to be ready.

Your Sample Box ID (use letters or numbers) ☐☐☐☐☐ **Sample Track & Field ID** (use letters or numbers) ☐☐☐☐☐☐☐☐☐☐

CROP INFORMATION

Crop to be Grown		Last Crop (if a legume)		
Crop Code # (from list on back)	Name	Crop Code # (from list on back)	Name	Yield Bu/A, etc.
☐☐☐		☐☐☐		

SOIL INFORMATION

Last Lime Application		Check ☑ if	Prominent Soils in Field (see back)			Your Yield Estimate	
Months Previous	Rate Ton/Acre		Soil Map Unit Symbol for:*	Percent (%) of Field	*or*	(For crop to be grown)	Circle Units
☐ –	☐ 0	☐ Field has artificial drainage	Largest area _____	_____	*or*		Tons/Acres
☐ 0 – 6	☐ 0.1 – 1.0	☐ Soil is a Histosol	2nd Largest Area _____	_____			Bushels/Acres
☐ 7 – 12	☐ 1.1 – 2.0	☐ Manure will be applied	3rd Largest Area _____	_____			Acres/AU*
☐ 13 – 18	☐ 2.1 – 3.0		* Soil Map Unit Symbol may be obtained from a County Soil Survey Report or a NRCS Conservation Plan. Include only areas that make up at least 20% of field.		*or*	* Animal Unit= one 1,000 lb cow w/calf or two 500 lb steers, or five ewes w/lambs.	
☐ 19+	☐ 3.1+						

SOIL TEST DESIRED AND FEES

	COST PER SAMPLE IN-STATE	COST PER SAMPLE OUT-OF-STATE
☐ Routine (soil pH, P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, and estimated CEC)	No-Charge	$16.00
☐ Organic Matter	$ 4.00	$6.00
☐ Soluble Salts	$ 2.00	$ 3.00
☐ Fax Results: FAX # (_____) _____	$ 1.00	$ 2.00

Method of Payment: ☐ Check Enclosed *or* ☐ Bill my Business FIN or SS# required for billing _____

Send in payment along with soil sample and form; make check or money order payable to ***"Treasurer, Virginia Tech."***

Field Crops

Corn:
- Grain, No Till #1
- Grain, Conventional #2
- Silage, No Till #3
- Silage, Conventional #4
- Irrigated #20

Sorghum:
- Grain #5
- Silage #22

Canola #21
Wheat #6
Barley #7
Barley Silage-Corn Silage Rotation #23
Oats #8
Rye, Grain or Silage only #9
Double-Crop Rotations:
- Small Grain – Grain Sorghum #12
- Small Grain – Soybean #11

Soybeans #10
Peanuts #13
Corn-Peanut Rotation #19
Cotton #14
Tobacco:
- Flue-Cured #15
- Dark-Fired #16
- Sun-Cured #17
- Burley #18

Forage Crops – Establishment

Alfalfa, Alfalfa-Grass #30
Tall Fescue/Orchardgrass without or with Clover (Red/Ladino) #31
Bermudagrass #34
Sorghum-Sudan, Millet, Sudan #35
Small Grains with Winter Annual Legumes for Hay or Grazing #36
Wildlife/Erosion Control Mixture #32

Forage Crops – Maintenance

Hay:
- Alfalfa or Alfalfa with Grass #37
- Tall Grass with Clover #38
- Tall Fescue/Orchardgrass #44
- Bermudagrass #47

Pasture:
- Fescue/Orchardgrass - Clover #40
- Native or Unimproved #42
- Bermudagrass #46

Stockpiled Tall Fescue #45
Switchgrass #48

Commercial Vegetable Crops

Asparagus – Nonhybrid Strains #50
Asparagus – New Hybrid #51
Bean, Lima #52
Beans, Snap #53
Broccoli, Cauliflower #54
Cabbage #55
Brussels Sprouts, Collards #56
Cucumbers #57
Muskmelons #58
Onions, Bulbs #59
Onion, Scallions #60
Peas #61
Peppers #62
Potatoes, White #63
Potatoes, Sweet #64
Pumpkins #65
Spinach #66
Squash #67
Sweet Corn – Fresh Market #69
Sweet Corn – Processing #70
Tomatoes – Fresh Market #71
Tomatoes – Process, Multiple Harvests #72
Tomatoes – Process, Single Harvest #73
Watermelons #74

Commercial Turf Production

Sod Production:
- Kentucky Bluegrass, Fescue #90
- Bermuda, Zoysia #91

Fruit Crops

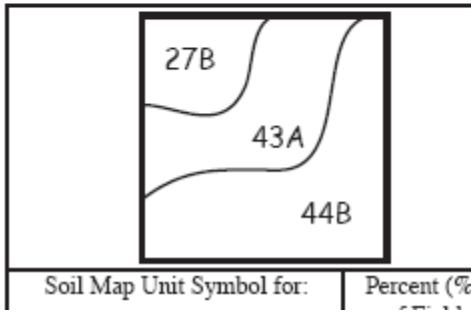
Grapes #94
Apples # 95
Peaches #96
Strawberries #97
Blueberries #98
Blackberries, Raspberries #99

Commercial Forest Tree

Hardwood:
- Establishment #105
- Maintenance #106
- Nursery, Black Walnut #107

Pine:
- Establishment #109
- Maintenance #110
- Nursery #111

Christmas Trees:
- Frazer Fir, Norway Spruce, Hemlock #113
- White Pine, Virginia Pine, Scotch Pine #114
- Blue Spruce, Red Cedar #115
- Nursery #116



Soil Testing Results

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
00001		Orchardgrass/Fescue-Clover Pasture (40)		18+		16C 56	16D 44			

LAB TEST RESULTS (see Note 1)

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	55	58	2075	560	7.6	11.6	0.3	5.2	0.8	
Rating	H-	L+	H+	VH	SUFF	SUFF	SUFF	SUFF	DEF	

Analysis	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
Result	7.0	N/A	7.6	N/A	100.0	68.5	30.5	1.0	

FERTILIZER AND LIMESTONE RECOMMENDATIONS

Crop: Alfalfa, ALF-Grass - Estab (30)

Lime, Tons/Acre		Fertilizer, lb/A		
Amount	Type	N	P205	K20
0		0	110	150

121. P2O5 and K2O recommendations will supply the needed nutrients for establishment and one harvest year's growth.

Lime & Nutrients

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
00001		Orchardgrass/Fescue-Clover Pasture (40)		18+		16C 56	16D 44			

LAB TEST RESULTS (see Note 1)

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	55	58	2075	560	7.6	11.6	0.3	5.2	0.8	
Rating	H-	L+	H+	VH	SUFF	SUFF	SUFF	SUFF	DEF	

[illegible]	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
[illegible]	7.0	N/A	7.6	N/A	100.0	68.5	30.5	1.0	

FERTILIZER AND LIMESTONE RECOMMENDATIONS

Crop: Alfalfa, ALF-Grass - Estab (30)

Lime, Tons/Acre		Fertilizer, lb/A		
Amount	Type	N	P205	K20
0		0	110	150

121. P2O5 and K2O recommendations will supply the needed nutrients for establishment and one harvest year's growth.

Not All Lime Is Created Equal

Chemical Composition and Calcium Carbonate Equivalent of Certain Liming Materials

Lime material	Calcium carbonate equivalent
Calcitic lime $CaCO_3$ (pure)	100
Dolomitic lime $CaCO_3 \cdot MgCO_3$ (pure)	108
Burned lime CaO	150-175
Hydrated lime $CaOH_2$	110-135
Marl $CaCO_3$	70-90
Slags $CaSiO_3$	60-90

Size of Particles	Years after Application	
	One	Four
Coarser than 8 mesh	5	15
8 to 30 mesh	20	45
30 to 60 mesh	50	100
Finer than 60 mesh	100	100

Particle Size	% Effective Material
Larger than 10 mesh	0
Between 10 and 50 mesh	50
Less than 50 mesh	100

https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y

N-P-K Recommendations

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
00001		Orchardgrass/Fescue-Clover Pasture (40)		18+		16C 56	16D 44			

LAB TEST RESULTS (see Note 1)

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	55	58	2075	560	7.6	11.6	0.3	5.2	0.8	
Rating	H-	L+	H+	VH	SUFF	SUFF	SUFF	SUFF	DEF	

Analysis	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
Result	7.0	N/A	7.6	N/A	100.0	68.5	30.5	1.0	

FERTILIZER AND LIMESTONE RECOMMENDATIONS

Crop: Alfalfa, ALF-Grass - Estab (30)

Lime, Tons/Acre		Fertilizer, lb/A		
Amount	Type	N	P205	K20
0		0	110	150

121. P2O5 and K2O recommendations will supply the needed nutrients for establishment and one harvest year's growth.

Compare Results

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
		Native or Unimproved Pasture (42)		18+		16C 40	42C 30	16B 30		II

LAB TEST RESULTS (see Note 1)

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	31	138	2063	494	8.8	17.1	0.3	6.1	0.5	
Rating	M+	M	H+	VH	SUFF	SUFF	SUFF	SUFF	SUFF	

Analysis	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
Result	6.8	6.40	7.4	0.8	99.2	69.4	27.4	2.4	

FERTILIZER AND LIMESTONE RECOMMENDATIONS

Crop: Native or Unimproved Pasture (42)

Lime, Tons/Acre	
Amount	Type
0	

Fertilizer, lb/A		
N	P205	K20
See Comment	75	100

825. If stand contains less than 25 percent clover, apply 40-60 lbs N/A.

131. If additional production is needed later on, apply 40 to 60 lbs/A of N during the grazing season. If you are planning to overseed a legume into the stand, omit the N recommendation.

123. P2O5 and K2O recommendations are for single applications made every 3 to 4 years. After this time, soils should be re-tested.

Micro-Nutrients

SAMPLE HISTORY

Sample ID	Field ID	LAST CROP		LAST LIME APPLICATION		SOIL INFORMATION				
		Name	Yield	Months Prev.	Tons/Acre	SMU-1 %	SMU-2 %	SMU-3 %	Yield Estimate	Productivity Group
00001		Orchardgrass/Fescue-Clover Pasture (40)		18+		16C 56	16D 44			

LAB TEST RESULTS (see Note 1)

Analysis	P (lb/A)	K (lb/A)	Ca (lb/A)	Mg (lb/A)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	B (ppm)	S.Salts (ppm)
Result	55	58	2075	560	7.6	11.6	0.3	5.2	0.8	
Rating	H-	L+	H+	VH	SUFF	SUFF	SUFF	SUFF	DEF	

Analysis	Soil pH	Buffer Index	Est.-CEC (meq/100g)	Acidity (%)	Base Sat. (%)	Ca Sat. (%)	Mg Sat. (%)	K Sat. (%)	Organic Matter (%)
Result	7.0	N/A	7.6	N/A	100.0	68.5	30.5	1.0	

FERTILIZER AND LIMESTONE RECOMMENDATIONS

Crop: Alfalfa, ALF-Grass - Estab (30)

Lime, Tons/Acre		Fertilizer, lb/A		
Amount	Type	N	P205	K20
0		0	110	150

121. P2O5 and K2O recommendations will supply the needed nutrients for establishment and one harvest year's growth.

Where do these recommendations come from?

Nutrient Removal By Crops

Crop	Plant part	Acre yield	N	P as P_2O_5	K as K_2O	Ca	Mg	S	Cu	Mn	Zn
			lbs								
Hay											
Alfalfa		4 tons	180	40	180	112	12	19	0.06	0.44	0.42
Bluegrass		2 tons	60	20	60	16	7	5	0.02	0.30	0.08
Coastal bermudagrass		8 tons	300	70	270	59	24	35	0.21	-	-
Red clover		2.5 tons	100	25	100	69	17	7	0.04	0.54	0.36
Soybean		2 tons	90	20	50	40	18	10	0.04	0.46	0.15
Timothy		2.5 tons	60	25	95	18	6	5	0.03	0.31	0.20

P (lb/A)	K (lb/A)
55	58
H-	L+

Those numbers are almost the same why would they have different levels. If it says H-, why do I need to fertilize? There is enough P for one crop year, but P can be built up the soil. In this sample there is grossly too little of K to get through the season.

https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y

https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y

Fertilizer Recommendations

Fertilizer, lb/A		
N	P205	K20
0	110	150

- Fertilizer sold as N%-P_2O_5%-K_2O%
- 10-20-20 =10% N - 20% P_2O_5 -20% K_2O
- How much fertilizer do you need from these recommendations?
- Do you need 110 lbs of fertilizer or 150 lbs of fertilizer?
- No, you need to take the amount of lbs/ acre recommended and divide by % of each in the fertilizer to know how to satisfy the need.
- Example: 150 lbs of K needed Fertilizer is 10-20-20

150 lbs of N / .2 = 750 lbs of that fertilizer to satisfy the K

Fertilizer

- Bulk Fertilizer
- Blended Fertilizer
- Special products such as Osmocote Slow Release or Nutrisphere
- Organic Fertilizers
- Manure/Compost
- Legumes

Fertilizer Costs

Fertilizer	Price ($/ton)	Price ($/lbs)	Price ($/lb N)	Price ($/lb P)	Price ($/lb K)
19-19-19	557	0.28	1.47	1.47	1.47
0-0-60	510	0.26	N/A	N/A	0.43
46-0-0	440	0.22	0.48	0.00	0.00
18-46-0	680	0.34	1.89	0.74	N/A
10-20-20	489	0.24	2.45	1.22	1.22

*Old prices just for example

Management Recommendations

- **Take a soil test!!!! See what is actually going on.**
- **Your cheapest fertilizer is lime.**
- **Use a legume as a cover crop or in the forage mixture and just worry about P & K.**
- **Sit down and compute your best option.**
- **Find out more about products or do a small test plot before buying special products.**
- **Call your Extension Agent if you have any questions.**

Resources

- Stevens, Gene, Peter Motavalli, Peter Scharf, Manjula Nathan, and David Dunn. "Integrated Pest Management: CROP NUTRIENT DEFICIENCIES & TOXICITIES." University of Missouri Extension Service. 2002. http://muextension.missouri.edu/xplor/agguides/pests/ipm1016.htm

- Hunnings, J. R. and Stephen J. Donohue. "Soil Sampling For The Home Gardener." Virginia Cooperative Extension. 2009. http://pubs.ext.vt.edu/452/452-129/452-129.pdf.

- Brann, Daniel, David L. Holshouser, and Gregory L. Mullins. "Agronomy Handbook." Virginia Cooperative Extension. 2000. https://vtechworks.lib.vt.edu/bitstream/handle/10919/48840/424-100_pdf.pdf?sequence=1&isAllowed=y

- "Soil Quality." Natural Resource and Conservation Service-USDA. Accessed January 12, 2010. http://soils.usda.gov/SQI/concepts/concepts.html