SOIL HEALTH

DESCRIPTION

Soil health is based on a variety of characteristics, including organic matter, salinity, structure and compaction, available nutrients, pH, water holding capacity and erosion levels. Together, these characteristics allow soil to serve a variety of functions: supporting the growth of crops (and therefore animals), regulating the distribution of rain and irrigation water and providing filtration to improve water as it infiltrates through soils.

Under current production methods, soil health and its corresponding contribution to farm production is under threat by increasing levels of soil degradation and erosion. The 1999 National Resources Inventory of the USDA reports that 1,700 megatonnes (million metric tonnes) of soil eroded from U.S. land in 1997.[138] This is enough to fill a fully loaded freight car train that would encircle the planet seven times.[139] Also, soil organic matter in some areas of North America, has declined 30-60% since the start of cultivation.[140] These effects make farmers' jobs increasingly difficult, as it becomes necessary to improve degraded soil quality with cost and time intensive inputs. Soil erosion is particularly problematic since its effects are irreversible.

Healthy soils are not only important to farm production, but also to overall environmental health. When soil is eroded via runoff, sediments, in addition to being a water pollution source, can carry nutrients or pesticide residues that further pollute surface waters. Soil that is compacted worsens this problem in that impacted soils cannot absorb as much water, increasing the amount of runoff. Unhealthy soil also contributes to particulate matter air pollution when loose topsoil is transported off of the farm via wind.

This module focuses on best management practices to maximize soil quality and health in order to maximize production and minimize erosion and pollution to water or air. Recommended areas of management include monitoring overall quality, minimizing erosion, maximizing organic content and preventing soil compaction.

INCENTIVES FOR CHANGE

- **Regulations:** The most recent 2002 Farm Bill includes an amendment to the Food Security Act of 1985 requiring that conservation systems must be implemented for agricultural operations on federally-designated "highly erodible land" (HEL). Conservation systems must protect land from excessive soil erosion and non-compliance can result in a producer becoming ineligible for numerous USDA benefits. In 1997, Vermont had approximately 125,000 acres of HEL. Conservation efforts undertaken now can mean assured compliance with this regulation and can safeguard a farmer's operations in the future. Technical and financial assistance is often available for farmers to implement both voluntary and compliance-driven conservation initiatives. See the "Further Information" section for details.

- **Cost Savings:** Maintaining healthy soils encourages maximum yields, meaning that farmers can maximize the amount of feed that they grow on the farm and correspondingly reduce costs of purchased feed. Healthy soils can also support crop growth with fewer inputs of commercial fertilizers and pesticides, thereby decreasing costs for these inputs, saving farmers time on their application and providing more efficiently produced crop yields. Benefits received now will be compounded in the future as soil health becomes increasingly better and increasingly self-sustaining.

- **Governmental Cost Sharing:** The 2002 Farm Bill re-authorized funding to help farmers adopt conservation strategies directed at improving soil quality, water quality, air quality and wildlife habitat. Through this program, farmers can be paid to implement new practices that will benefit their operations as well as the environment. For example, soil quality improvement practices can reduce impact to the environment and improve farmers' yields, thus improving revenues and lowering costs overall. Cost sharing is generally up to 75%, though certain farmers may be eligible for 90%, and incentive payments can last up to three years to promote continued use and long-term adoption of management strategies.

ASSESSMENT QUESTIONS

For all questions, please choose the categories that best identify your current management practices. Use the Summary sheet on the last page of this module to evaluate overall performance.

SOIL ORGANIC MATTER

❑ 1. Soil organic matter is not monitored and inorganic fertilizers are used to provide a large portion of crop nutrients.

❑ 2. Some effort is made to increase soil organic matter through a) restricted tillage practices, b) cover crops, c) use of least oxidizing inorganic fertilizers or precision fertilizer applications, d) crop rotations, or e) use of manures or composts on fields.

❑ 3. A strong effort is made to maximize and maintain soil organic matter. Soil is tested for organic content and two practices from #2 are used as appropriate to soil need.

❑ 4. In addition to #3, the use of inorganic fertilizer is completely or almost completely eliminated.

The elements of soil, including plant roots, that were once alive as well as the living organisms are termed 'soil organic matter.' Organic matter is essential to soil health and productivity due to the myriad of services and benefits it provides. Examples include stabilizing and holding the soil together; improving the soil's ability to store and transmit air, water and nutrients to crops; helping maintain a balanced population of soil organisms; and helping to prevent soil compaction. The net benefits are more productive crop harvests with fewer inputs, reduced runoff, and minimized soil erosion.

Cover crops contribute to soil organic content by increasing the plant material that is left on the soil and by preventing erosion of topsoil that is rich in organic material. Tillage and overuse of inorganic fertilizers, particularly nitrogen, instead of using organic materials to provide fertility, accelerates the rate of decomposition of organic material in the soil, thereby causing loss of this material at a faster rate. These practices should therefore be minimized. Manures, which increase organic matter in the soil, should be used to supply soil with needed nutrients.

USE OF COVER CROPS AND VEGETATIVE AREAS

❑ 1. No effort is made to vegetate areas of bare soil on the farm; cover crops are never used.

❑ 2. Some effort is made to vegetate areas of bare soil on the farm. Soil is covered some of the time/in some areas by vegetative plantings, buffer strips, pasture, other perennial crops and seasonal crops. Cover crops are sometimes used.

❑ 3. Bare soil on the farm is kept to a minimum via vegetative plantings, buffer strips, pasture, other perennial crops and seasonal crops. Cover crops are used every year to maximize soil coverage and soil benefits.

❑ 4. In addition to #3, the cover crop type and timing are strategically chosen, based on farm characteristics such as soil type and traditional crop grown, to maximize benefits to soil.

Plantings such as cover or perennial crops, grass, and hay hold soil in place, prevent compaction of soil, improve tilth,[1] curb runoff and nutrient loss. Plant cover is also beneficial in that it increases organic matter and biological activity in the soil, which is beneficial to soil quality and plant growth. When cover crops are legumes such as alfalfa, clover or soybeans, they provide an added benefit of fixing nitrogen into the soil for use by future crops. Cover crops provide the additional benefit that yields can be sold or used as feed for cows. It is important to manage any plantings well by maintaining appropriate practices with respect to nutrient application and pesticide use.

CROP ROTATION

- ❑ 1. Crops are not rotated and most fields have corn or other high intensity row crops.
- ❑ 2. Crops are rotated every four or more years and rotation tends to include high intensity row crops and with small grain (oats, wheat, etc.) crops.
- ❑ 3. Crops are rotated at least once every three years and rotation includes row crops and grass or legume forage crops. Some effort is made to utilize crop rotation to optimize nutrient and pest management.
- ❑ 4. Crops are rotated at least once every three years and grass or legume forage crops are grown more often than row crops. Crop rotations are specifically planned to optimize nutrient and pest control.

Crop rotation leads to greater quantity and diversity of soil organic material, improves nutrient availability, and can help control pests. Including legume crops in the rotation will provide the needed diversity while also fixing nitrogen in the soil. Other crops can also help prevent nutrient leaching. The Michigan State University Agriculture Experiment Station found that, with regard to nutrient leaching, wheat never loses more than 20 pounds of nitrogen per acre per year, as compared to continuous corn, which leaches up to 100 pounds.[141] Various rotations may reduce nitrogen leaching 30-50% as compared to growing continuous corn.[142] Crop rotation is beneficial economically, in that it can improve amount and diversity of yields and reduces the need for costly commercial fertilizers and pest-control chemicals.

TILLAGE PRACTICES

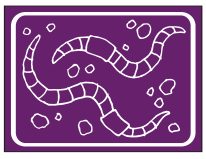
- ❑ 1. Tillage practices are undertaken without consideration of impacts to soil.
- ❑ 2. An effort is made to minimize/alter tillage use to benefit soil quality. Conservation tillage is used to maintain crop residue on soil; tillage is never done on wet soil; tillage is restricted to specific portion of fields (strip tillage); or tillage is avoided completely.
- ❑ 3. Tillage is strictly restricted as per one or more methods in #2, and resulting soil quality is monitored.
- ❑ 4. Perennial crops or crop rotation system is used, allowing for a no-till farming operation.

Adjusting tillage practices is beneficial for reducing soil compaction, minimizing erosion and improving organic matter content, all of which are environmentally and economically beneficial to the farmer. Soil compaction can restrict plant roots (reducing uptake of water and nutrients), affect moisture and soil temperatures (affecting organic matter and nutrient release), and decrease infiltration of water, which increases the levels of runoff and erosion.

Tillage should never be done on wet soil, as it is particularly susceptible to compaction versus dry soil. Conservation tillage leaves at least 30% of the soil surface covered by crop residues after planting, thereby protecting it from erosion and contributing to the organic matter and beneficial biological activity in the soil. Additionally, no-till or strip-tillage[2] practices minimize the area being tilled, thus minimizing soil compaction and removal of plant residues. Restrictive tillage practices can also result in cost savings by reducing the amount of fuel needed to run the equipment or eliminating the need to own and maintain the equipment.

[1] *Tilth is defined as soil's suitability to support plant or root growth by means of proper pore spaces for air and water filtration and movement and ability to hold adequate amounts of water and nutrients.*

[2] *Strip-tillage is defined as less than full-width tillage of varying intensity that is conducted parallel to the row direction. Generally no more than one-fourth of the plow layer is disturbed by this practice.*



SOIL CONSERVATION/EROSION PREVENTION

❑ 1. No consideration is given to the problem or prevention of soil erosion. Erosion rates are unknown.
❑ 2. An effort has been made to evaluate soil erosion, per the following evidence: presence of channels/gullies on fields, soil deposits at field margins or base of sloping areas, surface-crusted areas, exposure of lighter colored subsoil, and/or bare soil and loss of soil around plant roots.
❑ 3. In addition to #2, at least one step has been taken to minimize erosion, such as utilizing diversion ditches, maintaining vegetated buffer strips around bodies of water, using conservation tillage or creating windbreaks.
❑ 4. In addition to at least two actions from #3, at least one other action is taken: no-till or strip-till methods, mulches are used, manure or composts incorporated into fields, perennial crops are used on farm.

Soil erosion is the physical removal of surface soil material. Erosion can negatively impact crop production by contributing to the breakdown of soil structure and resulting in the loss of the uppermost soil layer. This top layer of soil has the highest levels of organic matter and biological activity, both of which are important for plant growth and overall soil health. It is very important to minimize erosion on the farm even if signs are not obvious that erosion is occurring. The loss of just 1/32 of an inch of topsoil, very difficult to notice on a farm, can equal a loss of 5 tons of soil per acre.[143]

Soil loss can be mitigated in several ways:

- Diversion ditches or windbreaks reduce soil loss by diverting excess water or wind from reaching vulnerable soils.
- Vegetated buffer strips can 'catch' runoff from fields, including soil, sediments, and nutrients, to help prevent water pollution and soil loss from farms.
- Adjusting tillage practices can help by leaving more crop residues on the soil, contributing to soil organic matter content and decreasing soil compaction and removal of plant residues, all of which minimize soil erosion.
- Mulches and manure or composts cover the soil and increase organic matter content, protecting soil from erosion and improving its quality. Perennial crops provide compound benefits by covering the soil and holding it in place with their roots.

SOIL QUALITY MONITORING

❑ 1. Soil quality on farm is not monitored.
❑ 2. Soil quality (including nutrient levels, salinity, and pH) is measured via soil tests every 5+ years but test results don't necessarily guide farm practices.
❑ 3. Soil quality is measured via soil tests every 3 years and test results and corresponding university recommendations guide farm practices.
❑ 4. In addition to #3, soil quality is measured via soil tests every 1-3 years and farm practices strictly follow corresponding UVM recommendations, including annual assessment of compaction, runoff, earthworms, and root health.

Regular soil testing (done at least once every 3 years) is the best way to ensure that soil remains healthy and productive, maximizing benefits to your farm. UVM and other experts offers soil test kits, analysis services and corresponding management recommendations that provide information such as soil pH, organic matter, available phosphorus and other nutrient levels, and fertility recommendations. At UVM, a basic soil test costs $9/sample and additional tests can be run for nominal fees (e.g. tests for organic matter cost an additional $3).

It is important to not only do the tests, but also to follow recommendations associated with the results. Results of these tests may include recommendations for nutrient application rates or improve soil characteristics such as pH or organic matter content. Maintaining high soil quality is increasingly beneficial over time as the soil is able to do the job that it is intended with fewer inputs (including time and money) from the farmer. If done every 1 to 3 years, soil testing is a non-time-intensive, inexpensive way to better understand and manage soil quality.

LINKAGES TO OTHER MODULES

Soil Health issues are closely tied to Biodiversity and Nutrient Management. The table below identifies where you can find more information on some of the topics mentioned in this module.

SOIL HEALTH TOPIC	OTHER MODULE(S)
Use of Inorganic Fertilizers	Nutrient Management
Soil Testing	Nutrient Management
Manure Use on Fields	Nutrient Management
Cover Crops	Biodiversity
Buffer Strips	Biodiversity

FURTHER INFORMATION

Additional details and information on the above can be obtained through the following programs.

- **The USDA Natural Resources Conservation Service** provides information on soil quality, offers tools for assessing soil quality and recommends best practices for improving soil quality. Information can be found at http://soils.usda.gov/sqi/soil_quality/what_is/index.html.

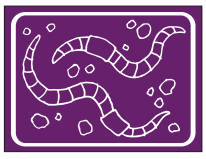
- NRCS also operates a **Conservation Reserve Program (CRP),** which provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. See http://www.vt.nrcs.usda.gov/programs/CRP/and http://www.fsa.usda.gov/dafp/cepd/crp.htm for more information.

- **The Environmental Quality Incentives Program (EQIP),** also run by the NRCS, was re-authorized by the 2002 Farm Bill to provide cost sharing up to 75% for farmers to implement conservation practices that address soil, water, air, wildlife and other natural resource concerns. Incentive payments may last up to 3 years to encourage farmers to continue utilizing new management practices. See http://www.nrcs.usda.gov/programs/eqip/ for more information.

- **Center for Sustainable Agriculture,** University of Vermont. http://uvm.edu/sustainableagriculture. 802-656-5459

- **Vermont NRCS,** has twelve regional field offices that can provide more assistance and information on all of the above. Contact the District Conservationist at Vermont NRCS State Office: 802-951-6796.

- **The Vermont Agency of Agriculture, Food and Markets** provides a clearinghouse of information on controlling non-point source pollution and runoff from dairy farms, including accepted agricultural practices (AAPs), best management practices (BMPs) and technical and financial assistance for projects. See http://www.vermontagriculture.com/pidnonpointsource.htm for more information. You can also call the Vermont Natural Resources Conservation Districts:
  - Windham, Bennington, Rutland, Windsor, Counties: 802-257-5621
  - Orleans, Essex, Caledonia, Orange, Washington Counties: 802-229-2720
  - Addison, Chittenden, Lamoille, Franklin, & Grand Isle Counties: 802-388-6746



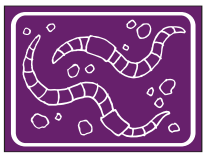
SUMMARY OF RESULTS FOR SOIL HEALTH

Instructions: In the table below, please record the score for the answer you selected for each question. For multiple-choice questions, the response number serves as your score for that category (i.e. choice # 2 is worth 2 points). For "check all that apply questions," please see scoring criteria for each question in the chart below. Once all responses have been completed, add up the answers and record the total.

QUESTION	ANSWER/SCORE
1. Soil Organic Matter	
2. Use of Cover Crops and Vegetative Areas	
3. Crop Rotation	
4. Tillage Practices	
5. Soil Conservation/Erosion Prevention	
6. Soil Quality Monitoring	
Total Score (Out of Possible 24)	

Interpretation: The next step in understanding your farm's performance in the category of Soil Health is to compare your results to best practices. Below is a table that ranks your performance from best practice (green) to practices that require improvement (red). Compare the number of points you received for your practices compared to optimal practices.

	Point Range	Interpretation
Green	21 - 24	Soil Health best practices are currently being employed on this farm.
Yellow	15 - 20	Farm is using some good practices regarding Soil Health. However there are some key areas that should be improved upon.
Red	6 - 14	Soil Health practices should be carefully evaluated and a strong effort should be made to adopt improved practices in several areas.



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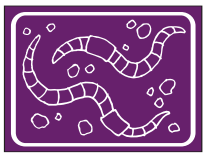

Footnotes

138 Heller, Martin C., Keoleian, Gregory A. "Assessing the sustainability of the US food system: a life cycle perspective." Agricultural Systems, 76, 2003, 1007-1041.

139 Ibid.

140 USDA Agricultural Research Service Website. National Programs Soil Resource Management "Component II: Nutrient Management." 25 Oct. 2003 <http://www.nps.ars.usda.gov/programs/programs.htm?npnumber=202&docid=349>.

141 Magdevski, Sonja. "Cropping Systems Can Benefit the Soil." Futures: Sustainable Agriculture. Fall/Winter 2000/Spring/Summer 2001, Vol. 18, No. 3/vol.19, nos. 1,2,3. Michigan State University Agricultural Experiment Station Website. 25 Nov. 2003. 3 Dec. 2003. < http://www.maes.msu.edu/Futures/fall_winter2001.pdf>.

142 Ibid.

143 "Soil Quality Resource Concerns: Soil Erosion" USDA NRCS Soil Quality Information Sheet. USDA Natural Resources Conservation Service Website. Soil Quality Information Sheet. "Soil Quality Resource Concerns: Soil Erosion" April 1996. 19 Nov. 2003. < http://soils.usda.gov/sqi/files/sq_two_1.pdf>.