Appendices

❖ Soil Quality/Soil Health Cards

1. Willamette Valley Soil Quality Card

2. Maryland Soil Quality Assessment Book

❖ Readings (not included in Web version)

1. *Farmer/Scientist Focus Sessions: A How-to Guide* (1993). D. McGrath, L.S. Lev, H. Murray, R.D. William. Oregon State University Extension Service, EM 8554.

2. *How Farmers Assess Soil Health and Quality* (1995). D.E. Romig, M.J. Garlynd, R.F. Harris, K. McSweeney. Journal of Soil and Water Conservation. 50(3): 229-236.

3. *The Changing Concept of Soil Quality* (1995). B.P. Warkentin. Journal of Soil and Water Conservation. 50(3): 226-228

Permission for reprints in this guide was obtained from authors and publishers.

❖ NRCS State Technical Notes

1. Maryland Soil Quality Assessment Book Technical Note

2. NRCS State Technical Note: Oregon Soil Quality Cards

❖ Soil Quality Card User Guide (not included in Web version)

Sample of the *Willamette Valley Soil Quality Card Guide* (1998). J. Burket et al. Oregon State University Extension Service, EM 8710. (Contact OSUES at: http://osu.orst.edu/extension/, or by faxing 541-737-0817.)

❖ Take-home Training Materials

Materials provided to (and added to the Guide by) participants in training sessions.

Willamette Valley Soil Quality Assessment Card

The Willamette Valley Soil Quality Assessment Card is a standard paper size (8.5” x 11”) pad, which includes user instructions, an assessment calendar, and multiple soil assessment cards (printed on Rite-in-the-Rain paper). The card was also produced as a fold-out brochure for convenient display and distribution.

Willamette Valley Soil Quality Card

Instructions

The *Willamette Valley Soil Quality Card* was developed by farmers in collaboration with the Natural Resources Conservation Service (NRCS), local soil and water conservation districts, and Oregon State University (OSU). It is a locally adapted field tool for farmers, educators, and agricultural support professionals such as soil conservationists, Extension agents, and agricultural industry personnel.

Regular use will allow you to assess current soil quality condition, record changes in soil quality, and compare fields and management practices. The card is most effective when filled out by the same person over time. It provides you with a qualitative assessment of the soil. Evaluation scores do not represent absolute measures or values. Use the card in more than one spot in your field to obtain a representative assessment.

The *Willamette Valley Soil Quality Card Guide* (EM 8710) was developed in conjunction with this card. It includes detailed information about each indicator listed on the card. The guide also contains techniques for making further judgments about each indicator.

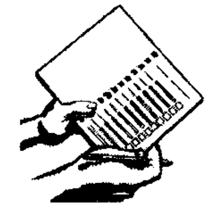
Suggested Assessment Calendar

Indicator	Before planting Early spring	Active crop growth Spring	Summer/Fall	Late fall	Winter
1. Soil structure and tilth	✔	✔	✔	✔	
2. Compacted layers	✔	✔	✔	✔	✔
3. Workability		✔		✔	
4. Soil organisms	✔	✔		✔	✔
5. Earthworm abundance	✔	✔		✔	✔
6. Plant residue	✔	✔	✔	✔	✔
7. Plant vigor		✔	✔		
8. Root growth		✔	✔		
9. Water infiltration	✔	✔	✔	✔	✔
10. Water availability		✔	✔		

Management, crop, and climatic factors determine the optimum time of soil quality assessment. The assessment times in this calendar are appropriate for the Willamette Valley of western Oregon.

How to use the card

1 Enter date, location, crop, year of planting (if perennial crop), and soil moisture level in the field. Select 1 to 5 representative spots in your field.



2 Use a shovel and a wire flag to probe the soil. Rate each indicator on a scale from 1 to 10. Refer to the rating guide to determine the score for each indicator.

3 Record your observations. Review and evaluate your scoring.

4 On the back page, write down current management practices. Record ideas for changes in management that you will implement as a result of your assessment.

Willamette Valley

Soil Quality Card

EM 8711

Date: ____________ Crop: ____________ Soil moisture

Field location: ____________ Year of planting: ____________

- ❑ Good for planting
- ❑ Too dry for planting
- ❑ Too wet for planting

Indicator	1	2	3	4	5	6	7	8	9	10 (Preferred)	Observations	Rating the indicator: 1	5	10
1. Does the soil have good structure and tilth?												Cloddy, powdery, massive, or flaky	Some visible crumb structure	Friable, crumbly
2. Is the soil free of compacted layers?												Wire flag bends readily; obvious hardpan; turned roots	Some restrictions to penetrating flag and root growth	Easy penetration of wire flag beyond tillage layer
3. Is the soil worked easily?												Many passes and horsepower needed	Medium amount of power and passes needed	Tills easily; requires little power to pull tillage implements
4. Is the soil full of living organisms?												Little or no observable soil life	Some (moving) soil critters	Soil is full of a variety of soil organisms
5. Are earthworms abundant in the soil?												No earthworms	Few earthworms, earthworm holes, or casts	Many earthworms, earthworm holes, and casts
6. Is plant residue present and decomposing?												No residue or not decomposing for long periods	Some plant residue slowly decomposing	Residue in all stages of decomposition; earthy, sweet smell
7. Do crops/weeds appear healthy and vigorous?												Stunted growth, discoloration, uneven stand	Some uneven, stunted growth; slight discoloration	Healthy, vigorously and uniformly growing plants
8. Do plant roots grow well ?												Poor root growth and structure; brown or mushy roots	Some fine roots; mostly healthy	Vigorous, healthy root system with desirable root color
9. Does water infiltrate quickly?												Water on surface for long periods after light rain	Water drains slowly; some ponding	No ponding after heavy rain or irrigation
10. Is water available for plant growth?												Droughty soil, requires frequent irrigation	Moderate degree of water availability	The right amount of water available at the right time
Other														

Flip to back for field notes

Printed on Rite-in-the-Rain paper

Field Notes

Current field management (tillage, fertilizer, irrigation, crop rotation, other)

Ideas for changes in field management

Credits

Twenty-four farmers representing a wide variety of farming operations and crops contributed to the design of this Willamette Valley Soil Quality Card. Development of the card was facilitated by Stefan Seiter, consultant in integrated agricultural systems; Arlene Tugel, soil scientist, USDA-NRCS Soil Quality Institute; John Burket, soil scientist, Agro-Ecology Northwest; Dan McGrath, Extension agent, Willamette Valley, Oregon State University; Richard Dick, professor of soil science, Oregon State University; and Cathy Seybold, soil scientist, USDA-NRCS Soil Quality Institute. Support was provided by NRCS field office staff, your local Soil and Water Conservation District, Oregon State University Extension Service personnel, and the USDA SARE program.

Funding for this project was provided by the USDA Natural Resources Conservation Service Soil Quality Institute.

Additional copies

The *Willamette Valley Soil Quality Card* (EM 8711) and the *Willamette Valley Soil Quality Card Guide* (EM 8710) are available at local OSU Extension Service, NRCS, and Soil and Water Conservation District offices or from Extension & Station Communications, Oregon State University, 422 Kerr Administration, Corvallis, OR 97331-2119. There may be a charge for postage and handling.

Published June 1998

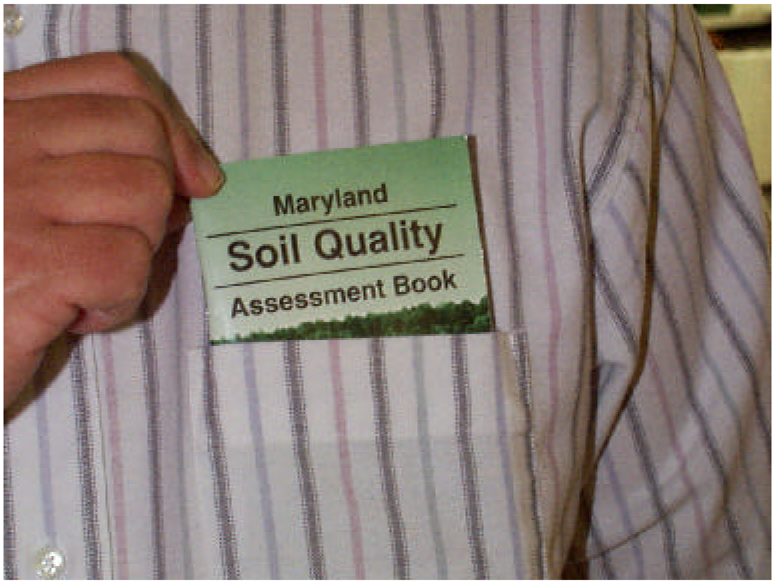
Map of field sampling locations

USDA

Soil Quality Institute
Natural Resources Conservation Service

Maryland Soil Quality Assessment Book

The Maryland Soil Quality Assessment Book is a pocket size (6.25" x 3.5") booklet, which includes user instructions, multiple soil assessment and field note sheets, and a table of descriptive terms for each farmer-selected soil quality indicator . Also included (and not featured in the sample presented here) are an assessment calendar, a section for personal notes, a two-year calendar, and a phone/address list.



About the Book

This soil quality assessment book is a locally adapted field tool designed by the University of Maryland in collaboration with the USDA-NRCS Soil Quality Institute and 17 Maryland farmers. It was developed to help users evaluate changes in soil quality as affected by field management. Regular use will allow you to record long-term changes in soil quality among different fields and various farming systems. The book is designed for farmers, but can also be used by agricultural support professionals such as soil conservationists, soil scientists, Cooperative Extension agents, and agriculture industry representatives.

How to Use the Card

Tools Required

- A shovel and a wire flag.

Soil Quality Assessment

- Select a field for evaluation and record the field and/or farm ID on an ***Assessment Sheet***. Use the ***Field Notes/Inputs Sheet*** to enter any other significant information such as inputs, crops, weather, soil moisture, or field conditions.

- Turn over a shovelful of soil about 6”- 8” deep. On the ***Assessment Sheet*****,** rate each indicator by marking an X or shading out to the box that best represents the value for that indicator. If you need more specific guidelines, refer to the ***Indicator Table*** for information on how to rate each indicator and to the ***Assessment Guide*** for the best time to do evaluations.

Notes

- This card is most effective when filled out by the same user over time and under similar soil moisture levels.

- The card is a **qualitative** assessment tool; therefore, evaluation scores do not represent any absolute measure.

- Using the card in more than one spot per field will provide a more accurate assessment.

Indicator Table

Indicator	Poor	Medium	Good
Earthworms	0-1 worms in shovelful of top foot of soil. No casts or holes.	2-10 in shovelful. Few casts, holes, or worms.	10+ in top foot of soil. Lots of casts and holes in tilled clods. Birds behind tillage.
Organic Matter Color	Topsoil color similar to subsoil color.	Surface color closer to subsoil color.	Topsoil clearly defined, darker than subsoil.
Organic Matter Roots/Residue	No visible residue or roots	Some residue few roots	Noticeable roots and residue
Subsurface Compaction	Wire breaks or bends when inserting flag.	Have to push hard, need fist to push flag in.	Flag goes in easily with fingers to twice the depth of plow layer.
Soil Tilth Mellowness Friability	Looks dead. Like brick or concrete, cloddy. Either blows apart or hard to pull drill through.	Somewhat cloddy, balls up, rough pulling seedbed.	Soil crumbles well, can slice through, like cutting butter. Spongy when you walk on it.
Erosion	Large gullies over 2 inches deep joined to others, thin or no topsoil, rapid run-off the color of soil.	Few rills or gullies, gullies up to two inches deep. Some swift runoff, colored water.	No gullies or rills, clear or no runoff.
Water Holding Capacity	Plant stress two days after a good rain.	Water runs out after a week or so.	Holds water for a long period of time without puddling.
Drainage, Infiltration	Water lays for a long time, evaporates more than drains, always very wet ground.	Water lays for short period of time, eventually drains.	No ponding, no runoff, water moves through soil steadily. Soil not too wet, not too dry.
Crop Condition (How well it grows)	Problem growing throughout season, poor growth, yellow or purple color.	Fair growth, spots in field different, medium green color.	Normal healthy dark green color, excellent growth all season, across field.
pH	Hard to correct for desired crop.	Easily correctable.	Proper pH for crop.
Nutrient Holding Capacity	Soil tests dropping with more fertilizer applied than crops used.	Little change or slow down trend.	Soil tests trending up in relation to fertilizer applied and crop harvested.

Assessment Sheet

Date__________________ Crop______________

Farm/Field ID _________________________

Soil Quality	**Poor**			**Medium**			**Good**		
INDICATORS	1	2	3	4	5	6	7	8	9
Earthworms									
Organic Matter Color									
Organic Matter Roots/Residue									
Subsurface Compaction									
Tilth/Friability Mellowness									
Erosion									
Water Holding Capacity									
Drainage infiltration									
Crop Condition									
pH									
Nutrient Holding Capacity									
Other (write in)									
Other (write in)									

Field Notes/Inputs

Farm I.D. ____________

Field I.D. ____________ Date ____________

Crop ____________ Acres ____________

Inputs

	Type	*Quantity*	*Price*
Fertilizer			
Lime			
Manure			
Cover Crops			
Pesticides			
Other			
Equipment			
Used			

Problems, Comments, Weather Conditions

____

____

____

Yields

Amount ____________

Units ____________

Moisture ____________

Price ____________

Maryland Soil Quality Assessment Book
Technical Note

This document provides technical information and additional background in support of the Maryland Soil Quality Assessment Book.

Indicator: Earthworms

Farmer's View
Farmers link earthworm abundance with factors such as ease of tillage and seedbed preparation, improved infiltration and drainage, and better crop performance.

Definitions, Discussion and Significance
The soil is a complex ecosystem that can support a large variety and abundance of life. Many different kinds of organisms are represented in the soil. Each species of soil life contributes to organic residue decomposition and nutrient cycling within the soil. If many different kinds of organisms are present in the soil, then nutrients are more likely to continue to be available for plant growth. Greater diversity and abundance of soil organisms also provide conditions that can suppress pests and disease.

Earthworms are important "keystone" participants in the soil food web and have long been recognized as an important part of healthy agricultural soils. Different types of earthworms occupy specific parts of the soil. Some species create deep burrows, while others live just under the litter layer at the soil surface. Some burrowing forms ingest large amounts of organic material and mineral soil and excrete them as casts at the soil surface. Earthworm casts contain more enzymes, bacteria, organic matter, and available plant nutrients than the surrounding soil. The movement of earthworms through the soil creates passageways that increase aeration and water infiltration. Their lubricating secretions bind soil particles together and help increase aggregate stability. Earthworms are particularly important in no-till systems as they are one of the main engines for soil mixing, which is essential for nutrient cycling and organic matter decomposition

Management Considerations
Management directly affects soil organism populations by providing a source of food. Incorporation of crop residue and cover crops can increase the diversity and abundance of soil life. Pesticides in the simazine, triazine and carbamate groups, and anhydrous ammonia fertilizers can suppress soil organism populations, particularly those of some of the larger predatory species. Although tillage is necessary to incorporate organic residues, it can disrupt the habitat of soil organisms. Loss of surface residue, which protects and feeds earthworms, can reduce earthworm populations.

Indicator: Organic Matter – Color and Roots/Residue

Farmer's View

Farmers recognize that organic matter is critical to many important functions in the soil such as infiltration, good tilth and nutrient cycling. They associate dark soil color with thickness of plow layer, water storage, drought tolerance, seed bed workability, and with soil fertility factors such as availability of plant nutrients. Farmers also view organic matter as the living, visible portion of the soil surface, often indicated by roots and residues in various stages of growth and decomposition. Presence of a variety of types of residue from the previous season indicates that the soil is alive. For example, partially decomposed residue suggests that organic matter has been returned to the soil and nutrients recycled, while larger intact pieces are valued for their ability to provide structure and tilth to the soil.

Definitions, Discussion and Significance

Soil color can provide insight into how a soil will behave under certain intended land uses. Examples include:

- Darker color of the plow layer is associated with organic residues and the resultant improvement to tilth, structure, available nutrients and water holding capacity.
- Soils dominated by bright colors tend to have fewer drainage problems that would restrict their use.

Color is also used to describe other features important to understanding the development and behavior of soil (peds, pores, concretions, nodules, castes etc.). Soil color (hue, value and chroma) is determined by comparison with a Munsell System color chart. Because soil color is altered by moisture the recorded value is indicated as either "moist" or "dry".

Organic matter percent is the weight of decomposed plant and animal residue and is expressed as a weight percentage of the soil material less than 2mm in diameter. Organic matter is formed when plant residue from a previous crop or added organic material such as manure or straw decomposes over time. When decomposition is active, soil organic matter will be in all stages of breakdown, from recognizable plant parts, to individual plant fibers, to dark staining humus. Soil organisms decompose plant residue and recycle it into many different forms that benefit the soil. Most of the decomposition that takes place in soils is due to microbial activity. As larger soil organisms consume organic residue, they break it down into smaller pieces which allow bacteria and fungi to work more efficiently. Active decomposition of plant residues is a good indicator that the biological community is thriving in the soil. No visible residue suggests that insufficient residues were produced and returned to the soil, while too much residue indicates that the soil organisms are unable to decompose the material. Residues in various stages of decomposition is most favorable since the larger pieces help provide tilth and structure to the soil, while smaller pieces are used as food for soil micro-organisms.

Organic matter is important to soil quality because it:

- increases the soil cation exchange capacity (it's ability to hold essential plant nutrients)
- provides decomposition products which glue soil particles into aggregates improving soil structure, water infiltration and tilth
- provides a food source for a diverse population of soil organisms that promote nutrient recycling, air and water movement within the soil
- represents the principle sources of N and S (and much of the P) for crops.

Management Considerations
Surface plant residues protect soil from the erosive impact of rain. When organic residue is distributed through the topsoil, it creates conduits for the movement of surface water into the soil. In this way the potential for erosion by water runoff is reduced. The organic fraction influences plant growth through its influence on soil properties. It encourages granulation and good tilth, increases porosity and lowers bulk density, promotes water infiltration, reduces plasticity and cohesion and increases available water capacity. It has a high cation adsorption capacity and is important to pesticide binding. As plant residues decompose they release nitrogen, phosphorous, and sulfur.

Organic matter can be increased by adding composted animal manures to the soil, reducing depth and frequency of tillage, leaving the stover and straw on the surface whenever possible, planting cover crops on ground that is usually fallow, and growing high residue crops, especially those with dense root systems such as small grains and corn. Rotations that include hay crops will also help increase organic matter.

Indicator: Subsurface Compaction

Farmer's View
Compaction that restricts crop roots to the upper few inches of soil layers increases production costs by increasing runoff, erosion, seedling mortality and susceptibility to crop damage during periods of drought. Compaction counter measures are frequently not cost effective so one of the best strategies is to avoid creating conditions which may cause compaction.

Definitions, Discussion and Significance
Bulk Density is a soil mass per given volume of soil. The higher the bulk density, the more tightly packed a given volume of soil is. When a soil is compacted, the amount of pore space is reduced, and the weight of a given volume of soil is increased. Density values can predict how well plant roots are able to extend into the soil. Equally important as bulk density are soil strength and loss of macro-porosity. The flag test in the Assessment Book reflects soil strength. Compaction mainly restricts roots when the soil is fairly dry and soil strength is high.

The volume available for plant root development can be seriously reduced by the presence of compacted, subsurface layers. Compaction can severely restrict air and water movement in the soil. Compacted soil properties also limit microbial activity and the ability of earthworms and other organisms to live in the soil.

Management Considerations
Compaction occurs when farm machinery passes over the same area of soil repeatedly, or, it can occur from only one pass, if it is made when the soil is wet. The weight of the equipment, the number of trips across the field, and the type of soil determine the degree of compaction. The more intensely the soil is tilled, the more likely it is to be compacted. Fewer trips across the field can reduce compaction. Compaction can be limited by not working the ground or avoiding heavy grain trucks and manure spreaders when the soil is too wet.

The sliding action of tillage equipment over the same layer of sub-soil can also create compaction. Clay becomes smeared across the tops of pores and makes an impermeable layer of soil.

Often, compacted layers are found just below the tilling zone. This depth is the downward limit of stirring and loosening action performed by the implements. Physically breaking through a deep compacted layer with sub-soiling equipment can help counteract deep compaction. Deep chiseling (ripping) can alleviate some compaction problems, but in some cases only for the short term. Certain types of tillage equipment such as moldboard plows and disk harrows can contribute to a plow pan since they exert downward force on the soil as they lift and turn.

Incorporation of cover crops and other organic residues can help build soil organic matter, which can be important in counteracting compaction. The natural cycle of freezing and thawing (more typical in Western MD) can break up a plow pan. Planting deep rooted forages such as alfalfa and eastern gamma grasses can also help break up compacted layers. Earthworms can eat through compacted layers if the soil is wet, primarily in clay and silty soils.

Indicator: Tilth/Friability/Mellowness

Farmer's View

A mellow soil will crumble well and feel "spongy when you walk on it," and feel "like cutting butter" when planting, according to Eastern Shore Maryland farmers. Tilth, friability and mellowness all relate to the relative workability of a soil during routine tillage, planting, cultivation, and harvest operations. Conversely, a soil poor in these characteristics will feel cloddy and heavy, and either blow apart or compact during tillage operations. Tilth is an important characteristic even if the ground is in no-till or minimum till.

Farmers often talk about tilth and friability and mellowness as properties which are hard to define with precision since they are so farm-specific. However, they all also agree that these properties are something that they can recognize immediately on their own land.

Definitions, Discussion and Significance

- *Soil Aggregate*s are soil particles (i.e., sand, silt and clay) held together in a single mass or cluster. The formation of stable soil aggregates results from the binding action of humus and other soil organic matter components, the activities of soil organisms, and the growth of plant roots in the soil. Natural aggregates are called peds. Clods are masses of soil produced by tillage, logging or other soil disturbing operations.

- *Aggregate stability* refers to the ability of natural aggregates to resist breaking apart as a consequence of wetness or tillage. If individual aggregates break apart easily, then the soil is said to have poor aggregate stability.

- *Soil Consistence* refers to the feel of the soil and the ease with which a lump can be crushed by the fingers.

- *Tilth* refers to the physical condition, or structure, of the soil as it influences plant growth. A soil with good tilth is very porous and allows rainfall to infiltrate easily, permits roots to grow without obstruction, and is easy to work. Tilth is also related to bulk density, which is the weight per unit volume of soil. Soils with lower bulk density tend to have higher porosity and better tilth. Soils with ample pore space and an even distribution of large and small pores will be well aerated, have good water holding capacity and infiltration rates and will be easy for roots to grow through. High aggregate stability preserves the larger pores by preventing clogging with loose particles.

Management Considerations

Soil structure and tilth are impacted directly by soil management. A seasonal or yearly assessment of this indicator may show whether current management practices are helping or hindering the free movement of air and water through the soil. Good management of organic matter to encourage earthworm activity and microbial decomposition will improve soil tilth and structure. Operations that allow erosion and compaction of the soil, such as leaving a field bare over winter or working a soil when it's too wet, will result in poor soil tilth and structure.

Indicator: Erosion

Farmer's View

Erosion is defined as the movement of topsoil and nutrients from production areas to sites where they are not wanted. Erosion is a serious threat to water quality; sediment is the primary cause of water pollution, nutrient runoff, the second. Soil erosion is detrimental to farmers as it leads to a loss of the most productive part of the soil.

Definitions, Discussion and Significance

- *Natural Erosion* is the relatively slow sculpturing of landscapes by climatic factors over geologic time.
- *Accelerated Erosion* is the rapid alteration of landscapes due to land disturbing activities such as urbanization, tillage, grazing, or timber cutting etc. These activities increase erosion rates by exposing the soil surface to wind and rain fall.

Management Considerations

The NRCS recommends numerous conservation practices to control erosion and improve soil and water quality.

Conservation Cover (327) provides guidelines for establishing and maintaining perennial vegetative cover on land retired from agricultural production. Covers help reduce soil erosion and sedimentation, improve water quality, and create or enhance wild life habitat.

Cover and Green Manure Crop (340) provides guidelines for establishment of a crop of close-growing, legumes, or small grain. Cover crops provide seasonal protection and add organic material to the soil to improve infiltration, aeration and tilth.

Conservation Crop Rotation (328) provides guidelines on growing crops in a recurring sequence on the same field. This practice can maintain and improve soil organic matter content, manage deficient or excess plant nutrients, improve water use efficiency, manage plant pests (weeds, insects and diseases) and reduce sheet and rill erosion by water and wind erosion.

Residue Management (329, 344) provides guidelines for managing amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops under Mulch Till, No-Till, Reduced -Till, Strip-Till, or Ridge-Till management systems. Improved residue management can reduce sheet and rill erosion and soil erosion by wind, maintain or improve soil organic matter content and tilth and conserve soil moisture.

Contour Buffer Strips (332) provides guidelines for establishment of narrow strips of perennial, herbaceous cover across slopes and alternated down slopes with wider cropped strips. Buffer strips can help reduce sheet and rill erosion, reduce transport of sediment and other water-borne contaminants down slope, on-site or off-site, and enhance wildlife habitat.

Contour Farming (330) provides guidelines for farming sloping land in such a way that preparing land, planting, and cultivating are done on the contours. This practice can reduce sheet and rill erosion and control water.

Field Border (386) provides guidelines for establishment of a strip of perennial vegetation at the edge of a field. This practice helps protect edges of fields that are used as "turn rows" or travel lanes for farm machinery. It can also help reduce travel over cultivated areas that are subject to compaction.

Indicator: Water Holding Capacity

Farmer's View
The ability of soil to hold enough water to allow normal development of crops and pasture throughout the production season. Adequate water storage in the soil reduces operation costs related to stand establishment, normal plant development, pesticide effectiveness, and irrigation operations.

Definitions, Discussion and Significance
Water held in soil pores that is extractable by plant roots is called *available water*. Due to suction forces within soil pores this water resists evaporation and percolation, but is not so strongly held that roots cannot absorb it. *Available Water Capacity* (AWC) is the volume of water that should be available to plants if the soil, inclusive of rock fragments, were at field capacity. It is commonly estimated as the amount of water held between field capacity and wilting point, with corrections for salinity, fragments, and rooting depth.

Management Considerations
Water holding capacity is largely determined by soil texture, but can be enhanced by increasing soil organic matter content. Practices that reduce compaction and lower bulk density such as organic matter additions and not traveling over fields when they are wet will improve water availability in soils. Management that improves aggregate stability and the number of fine aggregates will increase infiltration, giving the water more soil to hold, as well as increasing the amount of readily available water held.

Indicator: Drainage/ Infiltration

Farmer's View

Farmers relate these terms to the amount of time water remains on the soil surface, how well it penetrates the soil surface, and how much runs off from production areas. Ponded water delays field operations, kills-off low lying areas and can reduce harvest quality. Poor water infiltration can damage crops and reduce yields.

Definitions, Discussion and Significance

- *Water Infiltration* is the process of downward water movement into the soil under saturated conditions such as occurs after a heavy rain. An important factor in water infiltration is the porosity of the soil. The number, lengths, and diameters of pores determine water movement and retention in soils. Large pores (greater than 1/16th inch in diameter) are responsible for most of the flow through soils. Water infiltration is also subject to factors such as texture and slope. Sandy soils in general will have higher infiltration rates than silty or clayey soils. Water tends to drain more quickly from positions higher on the landscape. Soil structure is an important factor that controls water infiltration. Unstable soil aggregates disintegrate when wet and release small clay particles that clog pores. Compacted soils restrict water movement into deeper sub-soil layers where water could be stored for plant use.

- *Ponding* is standing water in a closed depression. Water is removed only by deep percolation, transpiration, or evaporation, or by a combination of these processes.

- *Drainage class* identifies the natural drainage condition of the soil. It refers to frequency and duration of wet periods. Some of the more common classes include: Excessively drained, well drained, moderately well drained, somewhat poorly drained and poorly drained. Each is used to help land users consider soil features during the planning phase.

- *Permeability* is the quality of the soil that enables water or air to move through it. Soil properties such as texture, structure, pore size, pore shape and density are used to predict permeability. Historically soil survey has used permeability as a term for saturated hydraulic conductivity. Permeability rates are used to predict soil suitability for irrigation and drainage systems, septic tank absorption fields, and terraces and other conservation practices.

- *Flooding* is the temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources.

- *Hydrologic Group* Soil Surveys group soils having similar runoff potentials under similar storm and cover conditions. Soil properties that limit runoff potential are those that influence infiltration rate into bare soil after prolonged wetting and when not frozen. Factors include: thickness of soil, depth to seasonal water table, rock and gravel content, depth to slowly permeable layer, and soil texture.

Soils with good infiltration will have less surface runoff and be more resistant to erosion. Good water infiltration means the soil will dry out and warm up more quickly after heavy rains.

Management Considerations

Management that promotes top soil with a loose granular or crumb structure composed of aggregates that maintain their integrity when wet will be conducive to good water infiltration. Tillage operations that preserve soil structure will promote good water infiltration rates. Partial incorporation or addition of residues improves infiltration, as coarsely fibrous material can help provide channels for water movement through the soil. Surface residue cover is also important in promoting high infiltration rates and preventing crusting.

Indicator: Crop Condition

Farmer's View
Farmers use crop condition as an assessment of crop health and development to minimize farm inputs and to maximize production. Farmers measure the condition of the crop by asking questions such as: is the crop vigorous, is there an even stand in the field, is the color strong and uniform?

Definitions, Discussion and Significance
Plant vigor is indicated by the health of individual plants in the field. The uniformity of growth shown by all crop plants in a particular field also suggests good plant vigor. With similar management, plants that emerge at about the same time should be ready for harvest about the same time. The plant is dependent on the root system to collect and transport nutrients and water essential to normal growth and development. Healthy plants often have root growth as extensive as above ground plant growth.

Good soil structure promotes plant vigor by providing suitable porosity, water regulation, and nutrient cycling throughout the growing season and encouraging development of an extensive root system that explores as much of the soil as possible. Compacted subsoil layers that reduce the effective root zone or that perch water for long periods can restrict root system development.

Soil organisms can inhibit the proliferation of certain root diseases caused by fungi, bacteria, and nematodes. Diverse populations of soil organisms are associated with good structure.

Management Considerations
It is important to determine whether the crop is under optimal management. If management was less than optimal (late planting, insufficient irrigation or rainfall, etc.), then plant vigor may not be a good soil quality indicator. The crop should be examined for pest or disease damage. It is important to determine if the disease problem is related to soil quality. For example, root borne diseases may be in part caused by poor soil quality in the form of compacted soil that remains saturated of long periods. Management that encourages good soil structure will help promote root growth. Cultivation and compaction can inhibit root growth. Factors that contribute to good plant vigor will be reflected in healthy roots as well.

Indicator: pH (Soil Reaction)

Farmer's View
A correct pH will help assure availability of plant nutrients to maximize crop, forage and pasture production. Excessively high pH can be avoided if rate and timing of applications are consistent with crop needs and soil properties.

Definitions, Discussion and Significance
An important effect of pH on plant growth is nutritional. The pH value of the soil influences the rate of plant nutrient release by weathering, the solubility of many materials in the soil, the amounts of nutrient ions stored on cation-exchange sites and the CEC. The pH is therefore a very good guide for predicting which plant nutrients are most likely to be deficient. Availability of all the plant nutrients is generally satisfactory at pH values between 5.8 and 7.5.

Soil Reaction (pH) is a numerical expression of relative acidity or alkalinity of a soil. Acid soils have pH values less than 6.6, neutral soils between 6.6 and 7.3 and alkaline soils greater than 7.3. The principle value of soil pH is the information it provides about associated soil characteristics. Soil fertility factors associated with pH include: CEC values, nutrient availability and release of toxic aluminum.

Management Considerations
In Maryland, soils are generally acidic and soil pH can often be readily corrected with additions of lime (dolomitic limestone is most typical). In fields managed with no or little tillage, the top inch or two must be monitored for pH as it can change very fast. A pH of 5.8 to 6.5 is best for most crops, although certain crops such as alfalfa prefer a pH of 7. A pH below 5.8 can cause certain herbicides to be inactivated, and at 5.2 Al and Mn can be released into the soil solution causing plant toxicity.

Organic matter acts as a significant buffer for pH. As organic matter decays into humus, it develops molecules which are able to take up or release H ions depending on the pH of the surrounding soil solution, helping the soil to maintain a fairly constant pH. Products of actively decomposing organic matter also complex with Al^+ in solution, rendering it non-toxic.

Indicator: Nutrient Holding Capacity

Farmer's View

Farmers view nutrient holding capacity as a process in which the soil acts as both a sink, and a source of nutrients. Important considerations for farmers are the capacity of the storage, the rate of release, and the ability of the soil to replenish itself and provide nutrients to following crops.

Definitions, Discussion and Significance

Soil materials possess a net surface charge allowing them to hold and retain charged nutrient forms against leaching. While both negative and positive charges are present, negative charges usually dominate. The net ability to hold, retain and exchange positively charged nutrients is referred to as Cation Exchange Capacity (CEC). Increasing the pH of the soil solution increases the CEC. Examples of positively charged (cations) are:

Potassium (K^+) Ammonium (NH_4^+) Calcium (Ca^{2+}) Magnesium (Mg^{2+}) Aluminum (Al^{3+})

Negatively charged ions (anions) are not attracted to negative surface charges and thus are more subject to leaching. Examples include:

Nitrate ($N0_3^-$) Chloride (Cl^-) Sulfate ($S0_4^-$) Phosphate ($H_2P0_4^-$)

Phosphate and sulfate are not leached as readily as the nitrate, particularly in soils with iron coated clays. Phosphate is also less mobile in soils because of it is not soluble, and binds readily with clays. Factors important to nutrient holding capacity are pH, amount and kind of organic matter, soil texture, and clay type.

Management Considerations

Soil test results will help predict whether the soil will provide nutrients fast enough to meet the crop's needs in the near future. Currently, soil tests are most reliable for P, K and Mg. While soils can be tested for other nutrients, interpretations are much less reliable. Soil tests can be valuable over the long run as they can show which soils are building nutrient levels and which ones are dropping.

There is room for misinterpretation as high soil test values can be achieved on soils with low nutrient holding capacity if the farmer has recently applied high levels of fertilizers. While heavy fertilization can lead to short term increased productivity, it can also to leaching and nutrient loss. This approach also does little to improve other aspects of the soil such as tilth or infiltration.

Nutrient holding capacity is best improved by increasing soil organic matter, which serves as both a sink and a source for plant nutrients, and directly impacts quantity, and timing of release. Feeding the soil with organic residues, cover crops and animal manure not only improves nutrient holding capacity, but improves soil structure, friability and infiltration and workability. If high nutrient sources of organic matter such as animal manures are used, it is important to know the nutrient values, particularly of N and P, before application, so as not to over-apply the material and cause leaching or build-up of excess nutrients.

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This document was developed by a partnership effort between the NRCS Mid-Atlantic IRT, the University of Maryland, the NRCS Soil Quality Institute, and NRCS Maryland. Some of the information for this tech note was adapted from Willamette Valley Soil Quality Guide from Oregon.

Technical Notes

U.S. Department of Agriculture Natural Resources Conservation Service
Portland, Oregon

Soils Technical Note NO. xx February 1998

- Draft -

Oregon Soil Quality Cards:
Farmer-developed conservation tools

Stefan Seiter
Soil Quality Card Project Coordinator
Dept. of Horticulture, Oregon State University
Corvallis, OR 97331

and

Steve Campbell
Soil Quality Specialist
USDA-Natural Resources Conservation Service
101 SW Main Street, Suite 1300
Portland, OR 97204

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About Soil Quality Cards

What is a Soil Quality Card?

The Soil Quality Card is a qualitative assessment tool that is developed collaboratively by local farmers, NRCS and Cooperative Extension. The Card is used to assess changes in soil quality that are affected by field management. A single Card covers a specific eco-region characterized by comparable natural resource and farming conditions. The Card's primary users are farmers, thus, their language and terminology is used on the Card. Soil Quality Cards also can be used as a communication and learning tool by agricultural support professionals (such as soil conservationists, agricultural industry representatives, and extensionists), educators, and others who are interested in soil quality and the impact of management practices on soil.

A Soil Quality Card contains farmer-selected soil quality indicators and associated descriptive terms. The indicators are based on farmers' practical experience and intimate knowledge of the local natural resources. Typically, the Card lists soil quality indicators that can be assessed without the aid of technical or laboratory equipment. Examples include compacted soil layers, abundance of earthworms, or water infiltration rate. Using a Soil quality Card involves the selection of representative locations in the field and the rating of each indicator guided by the descriptive terms. If space is available on the Card, users also record field notes or observations made during the assessment.

Soil Quality Indicator	poor medium good									Descriptive Terms		
	1	2	3	4	5	6	7	8	9	poor	medium	good
Soil tilth										Cloddy, massive or flacky	Some crumbs, balls up	Porous, crumbly, spongy
Water infiltration										Water on surface for a long period after rain/irrigation	Water drains slowly; some ponding	No ponding after heavy rain/irrigation

Figure 1: Example a Soil Quality Card

How to use Soil Quality Cards

A soil quality Card is primarily designed to be used by farmers to make soil quality assessments in the fields they manage. It is not used by resource professionals to determine whether quality criteria in the NRCS field Office Technical Guide (FOTG) are being met. For example, the FOTG contains criteria for soil resources concerns including soil tilth, crusting, water infiltration, organic matter, compaction, and contaminants. These soil resource concerns should be assessed using other more quantitative methods.

What are benefits of Soil Quality Cards?

The use and collaborative development of a Soil Quality Card has benefits to farmers and land managers, conservationists, and natural resources agencies.

For farmers the Card is:

- A tool to assess the impact of field management on soil quality (for example: comparing tillage, crop rotations, cover cropping, fertilizer, or pesticide treatments)
- A tool to keep records of soil quality
- A tool to detect soil quality changes over time (short-term during the growing season, and long-term over the course of several years)
- A tool to communicate with soil specialists (NRCS, University, agricultural industry professionals) about issues or problems related to soil quality and soil management
- A tool to identify researchable topics (the Card can guide research by farmers, agency, university, or private organizations)

For conservationists and extensionists the Card is:

- A tool to approach farmers
- A tool that allows communication and an exchange of ideas and learning between conservationists and farmers
- A tool to assess the impact of field management and to detect changes of soil quality over time (similar to benefits for farmers).

For the NRCS and Cooperative Extension the development of the Cards is:

- A way to increase farmers' voluntary conservation efforts
- A way that fosters a systems approach to conservation
- A way to build credibility from its constituency
- A way to facilitate collaboration and communication among local groups, state and federal agencies

How are Soil Quality Cards developed?

Involved in the development of Soil Quality Cards are Farmers, Soil and Water Conservation Districts, NRCS state and field office staff, and Cooperative Extension. A half-day farmer meeting is the core activity in the development. After the meeting, the information discussed by the participants is incorporated into a prototype of a Soil Quality Card. During the growing season, the prototype is tested and evaluated in the field. Field test feedback is then used to finalize the Soil Quality Card. Marketing and distribution follows printing of the Card . The entire design process is typically accomplished during a 9 to 12 month period.

Cards developed in different regions of the state will likely contain both similar and distinct features. Some soil quality indicators listed on different Cards may be the same (the terms farmers use, however, for the indicators may be different because farmers' terminology is very area-specific). Other indicators will only be only applicable a particular region. Format and layout features of Cards also may differ, making each Card a unique tool.

The Willamette Valley Soil Quality Card

Development of the Willamette Valley Soil Quality Card

The Willamette Valley Soil Quality Card was developed to provide leadership for a nation-wide project in which states are encouraged to develop local Soil Health/Quality Cards. A prototype of the Willamette Valley Soil Quality Card was developed after three regional grower meetings and one soil quality workshop in 1997. Twenty-four farmers, NRCS field and state personnel and Oregon State University researchers and extensionists participated in the meetings. During the 1997 growing season, the prototype was tested during multiple one-on-one farm visits and several grower field days. The final card was produced in 1998.

Features of the Willamette Valley Soil Quality Card

The Willamette Valley Soil Quality Card lists 10 soil quality indicators, a rating system for the indicator and a list of descriptive term that guide the rating for each indicator. The indicators fall into four categories:

- Soil physical indicators: Soil structure and tilth; Compacted soil layers; Workability
- Soil biological indicators: Abundance of living organisms; Abundance of earthworms; Plant residue decomposition
- Plant growth indicators: Crop health and vigor; Root growth
- Water movement indicators: Water infiltration; Water availability

The Willamette Valley Soil Quality Card features a simple rating system. For each indicator users check a box between 1 and 10; 10 being the most desirable condition for each indicator. The rating is guided by descriptive terms for three rating levels (least desirable, medium, best).

The Card layout is a 8.5 x 11" sheet that makes it easy to file the Card with other field data in the regular field notebook binder that most growers use. The front page provides blank space to record observations made during the assessment. The growers also record date, field location, crop, year of planting (if perennial crop), and soil moisture level on the front page.

On the back page growers list current field management and ideas for management changes that could be implemented as a result of the assessment. In addition space is provide to draw a map of sampling locations. A copy of the complete Willamette Valley Soil Quality Card is provided in the appendix.

Appendix: *The Willamette Valley Soil Quality Card*