Assessing and Managing Soil Quality for Sustainable Agricultural Systems

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SANREM CRSP

USAID FROM THE AMERICAN PEOPLE

INTRODUCTION

- The Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP)
- A U.S.A.I.D.-funded research program with projects in Latin America, Africa and Asia.
- Its objective is to support sustainable agriculture and natural resource management decision makers in developing countries by providing access to appropriate data, knowledge, tools, and methods of analysis; and by enhancing their capacity to make better decisions to improve livelihoods and the sustainability of natural resources.
- Provides an opportunity to investigate research issues, such as soil degradation and soil quality, across a wide range of environmental conditions and cropping systems.

INTRODUCTION

- Soil degradation is a major global environmental problem, having widespread and serious negative effects on water quality and biodiversity and promoting the emission of climate changing greenhouse gases (Eswaran et al., 1997).

- For example, the loss of potential productivity due to soil erosion world wide is estimated to be equivalent to some 20 million tons of grain per year (UNEP, 1999).

INTRODUCTION (cont.)

- **Almost 75% of Central America's agricultural land has been seriously degraded as has 45% of South America's and 11% of Asia's. (Scherr, 1999; Heerink, 2001).**

- **More than 50% of poor people live in rural areas and most of their livelihood is from agriculture. Increasing agricultural productivity is essential for significant poverty reduction (FAO, 2005).**

INTRODUCTION (cont.)

Definition of Soil Quality:

" the capacity of a soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Doran and Parkin,1994).

INTRODUCTION (cont.)

- **Soil quality** - depends on the capacity of a soil to perform a desired ecosystem function
- **Soil functions** –
  - sustaining biological activity, diversity, and productivity
  - regulating and partitioning water and solute flow
  - filtering, degrading, immobilizing and detoxifying organic and inorganic species
  - storing and cycling of nutrients
  - providing structural support

INTRODUCTION (cont.)

Possible soil quality indicators:

- Biological indicators – microbial biomass C and N, potentially mineralizable N, soil respiration
- Chemical indicators – pH, EC, Extractable N, P and K
- Physical indicators – soil texture, infiltration, bulk density, water holding capacity

USDA Soil Quality Testing Kit

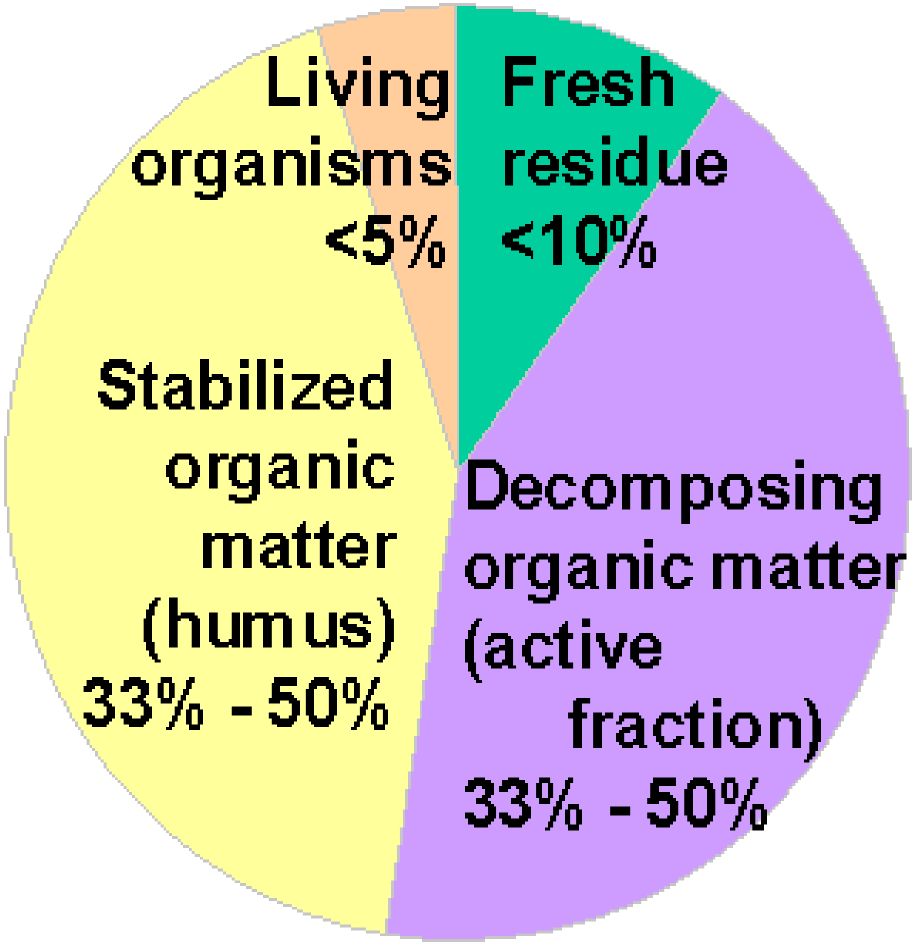
INTRODUCTION (cont.)

Soil organic matter (SOM) has a central role in soil quality

- **SOM is the complex mixture of organic materials derived from litter and root turnover and microorganisms whose chemical make up include carbohydrates, amino acids, protein, nucleic acids, lignins and humus (Mcholl and Gressel, 1995).**

- **SOM is considered to be an important soil quality index (SQI) because of its integral role in soil biological, physical, and chemical processes (Carter, 2002).**

Components of soil organic matter



www.soils.usda.gov

INTRODUCTION (cont.)

- Changes in small but relatively labile fractions of soil organic carbon (SOC) may provide an early indication of soil degradation or improvement in response to management practices.

- Labile fraction is the fraction of SOC that is thought to represent the active C pool, and serves as a sensitive indicator of change in management-induced soil quality (Islam and Weil, 2000).

INTRODUCTION (cont.)

- This carbon is the basis for a major soil nutrient reservoir.

- It is the heterogeneous mix of living and dead organic materials that are readily circulated through soil biological pools.

INTRODUCTION (cont.)

- There are many techniques that measure the soil organic matter over time both in the laboratory and field work and many of these techniques are used sequentially in analyses.
- So the changes in soil occur over time can then be measured to evaluate effects of different practices.

INTRODUCTION (cont.)

- **Little research has been conducted using spectroscopic analysis to test for soil quality on a range of soil samples with different soil characteristics from developing countries.**

- **Understanding the differences in perceptions of soil quality among the communities and surveying their preferences for the characteristics of a simple and reliable diagnostic test will assist in developing an appropriate method to assess soil quality that can be used across a wide range of environments.**

Objectives

1. Conduct a literature review of soil quality assessment techniques and identify practical techniques that would be appropriate to evaluate soil quality across SANREM activities.

Objectives (cont.)

2. Determine the efficacy of spectroscopic-based (i.e. near-infrared, mid-infrared, and visible range) analytical methods to evaluate soil organic matter fractions and soil quality in degraded and non-degraded soils in a wide range of environments.

Objectives (cont.)

3. **Assess community perceptions and indicators of soil quality, including differences in perceptions of soil quality due to differences in gender, environment and socio-economic factors.**

Hypotheses

- **H1: Spectroscopic methods (VIS-NIR-MIR) can be effective in assessing soil quality based on the status of soil organic C across a range of soils from different countries.**
- **H2 : A simple method to determine soil quality in the field can be developed using $KMnO_4$ and a portable field spectrometer or near infra-red spectroscopy.**
- **H3: Community perceptions of soil quality will be based on soil physical properties (e.g. soil color) and observed crop suitability and performance. Differences in these perceptions will be observed due to gender, environmental and socio-economic factors.**

Methodology

- Soils will be collected from depths of 0-10 to 0-20 cm from degraded and non-degraded agricultural fields (i.e., Sanborn Field, Bolivia, Ecuador, Zambia, and the Philippines)
- The soil will be freeze-dried, ground and sieved to a size fraction <2 mm diameter.
- Climatic information will be obtained.
- All samples will be analyzed by using spectroscopic methods.
- Soil texture, pH, CEC, total C, total N, water-soluble total organic C and total N, particulate organic matter C and N, plant available P (Bray 1 P), exch. K, Ca, and Mg also will be determined.

Methodology (cont.)

- Labile C – analyzed by $KMnO_4$ and visible range spectrophotometry (550 nm)
- Test of sample preparation method for DRIFT mid-infrared analysis
  - Extraction of HA fraction of SOM
  - Removal of mineral constituents using hydrofluoric acid
  - Analysis of intact soil

Methodology (cont.)

- **B. Diffuse Reflectance Fourier Transform Infrared Analysis (DRIFT)**

Methodology (cont.)

- For the routine analysis for carbon fractions of a large number of soils, a simpler and cheaper method of acceptable accuracy is needed.

- Spectroscopic methods analyzing the relative structural composition of SOC may provide a rapid, reliable, sensitive to the chemical of organic/ mineral components in soil and low-cost method to assess soil quality.

Methodology (cont.)

- **DRIFT analysis**

  - can assess the changes in SOM humification.

  - can assess the relative enrichment and depletion of specific functional groups within organic spectrum.

  - can quantify or assess the functional group composition of a wide range of SOM fractions.

Methodology (cont.)

- **Soil particles will be ground to a size fraction < 80 µm.**
- **Sample will be mixed with KBr and reground to powder consistency.**
- **The spectroscopy will be calibrated with a background consisting of powdered KBr and scanned under the same environmental conditions as sample-KBr mixtures.**
- **Absorption spectra will be converted to a Kubelka-Munk function using Grams/32 software package.**
- **Ratios of labile and recalcitrant functional groups will be generated by measurement of peak heights relative to spectra baselines using GRAMS software.**

DRIFT infrared spectra peak assignments and occurrences in physical and chemical organic matter fractions (adapted from Stevenson, 1982; Baes & Bloom, 1989)

Peak assignment	*wave number (cm^{-1})*
Mineral OH	3690
Mineral OH	3621
CH_2 symmetric stretch	2962-2950
CH_2 symmetric stretch	2850
CO-OH H bonded	2500
C=O stretch	1850
C=O ketonic, COOH	1735-1713
C=O, C=O-H bonded,	1650
C=C aromatic	1630-1608
Aromatic ring, amide	1509
CO, COOH, COC, phenol OH	1260-1240
Aliphatic, alcoholic OH	1190-1127
CO aliphatic alcohol	1080-1050
Aliphatic COC, aromatic ether, Si-O	1030
CH aromatic bend	779
COO salt, Mg/Si-O aliphatic	560

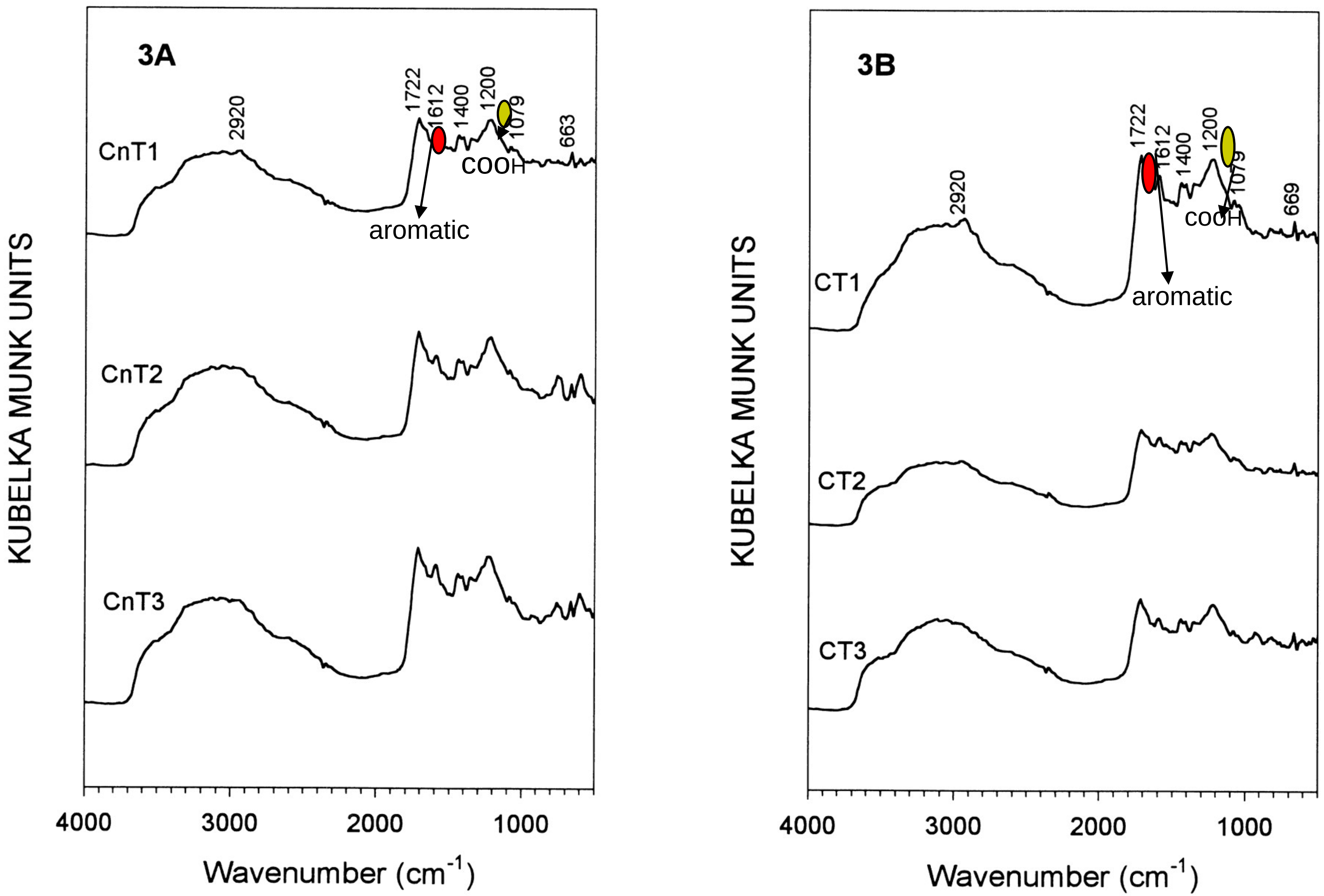
Methodology (cont.)

- **Ding et al., 2002, The study of soil organic matter characteristics as affected by tillage management.**

  The study was conducted using soil samples collected from the long-term conservation tillage (CnT) and conventional tillage (CT) research plots established in 1979 (Darlington, SC).

  The CT treatment consists of multiple disking (0-15 cm deep) and the use of field cultivators to maintain a relatively weed free surface. Surface disking and field cultivation have been completely eliminated in soil under CnT plots since 1979.

DRIFT spectra of humic acids under different tillage treatment CnT1, 0-5 cm; CnT2, 5-10 cm; and CnT3, 10-15 cm). CnT- conservation tillage and CT-conventional tillage treatment



Ratios of selected peak heights from DRIFT spectra of humic acids

HA	Depth (cm)	total O/R ratio $\frac{(1727+1650+1160+1127+1050)}{(2950+2924+2850+1530+1509+1457+1420+779}$
Conservation tillage		
CnT1	0-5	0.87 a
CnT2	5-10	0.69 b
CnT3	10-15	0.70 b
Conventional tillage		
CT 1	0-5	0.74 ab
CT 2	5-10	0.69 b
CT 3	10-15	0.67 b

** Means with different letters are significantly different P = 0.05*

Methodology (cont.)

- Ding et al., 2002. Results were concluded that

  - HA from conventional tillage was less aliphatic and more aromatic than HA from conservation tillage.

  - Aliphatic C content decreased with increasing depth for both conventional and conservational tillage.

  - Base on reactive/ recalcitrant (O/R) peak ratio comparisons, HA was more reactive in the top soil (0-5 cm) under conservation tillage than conventional tillage.

  - The ratio of O/R (reactive/recalcitrant) showed the highest in conservation tillage (CnT) at 0-5 cm, suggesting relatively enrichment of O associated C over time in CnT plots as compared with conventional tillage(CT).

Methodology (cont.)

- **Statistical analysis**

  - The ratio (O/R ratios) of reactive (O-containing) and recalcitrant (C, H and/or N) functional group generated from DRIFT peak heights will be examined.

  - Regression and correlation can be used to model the relationship between infrared spectral intensities and SOC.

  - Two-way analysis of ANOVA will be used to analyze different treatment applications effects on SOM. SAS will be used for each test at a 0.05 level of significance.

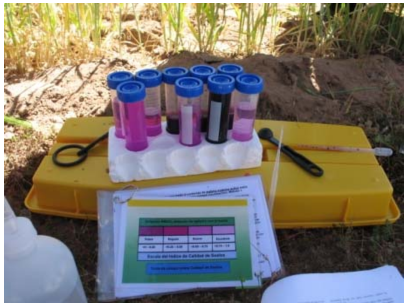
Methodology (cont.)

- **H2 : A simple method to determine soil quality in the field can be developed using $KMnO_4$ and a portable field spectrometer or near infra-red spectroscopy.**

- **a. portable field spectrometer**

  Using Pocket Colorimeter II Filter Photometer, user-programmable, 550 nm

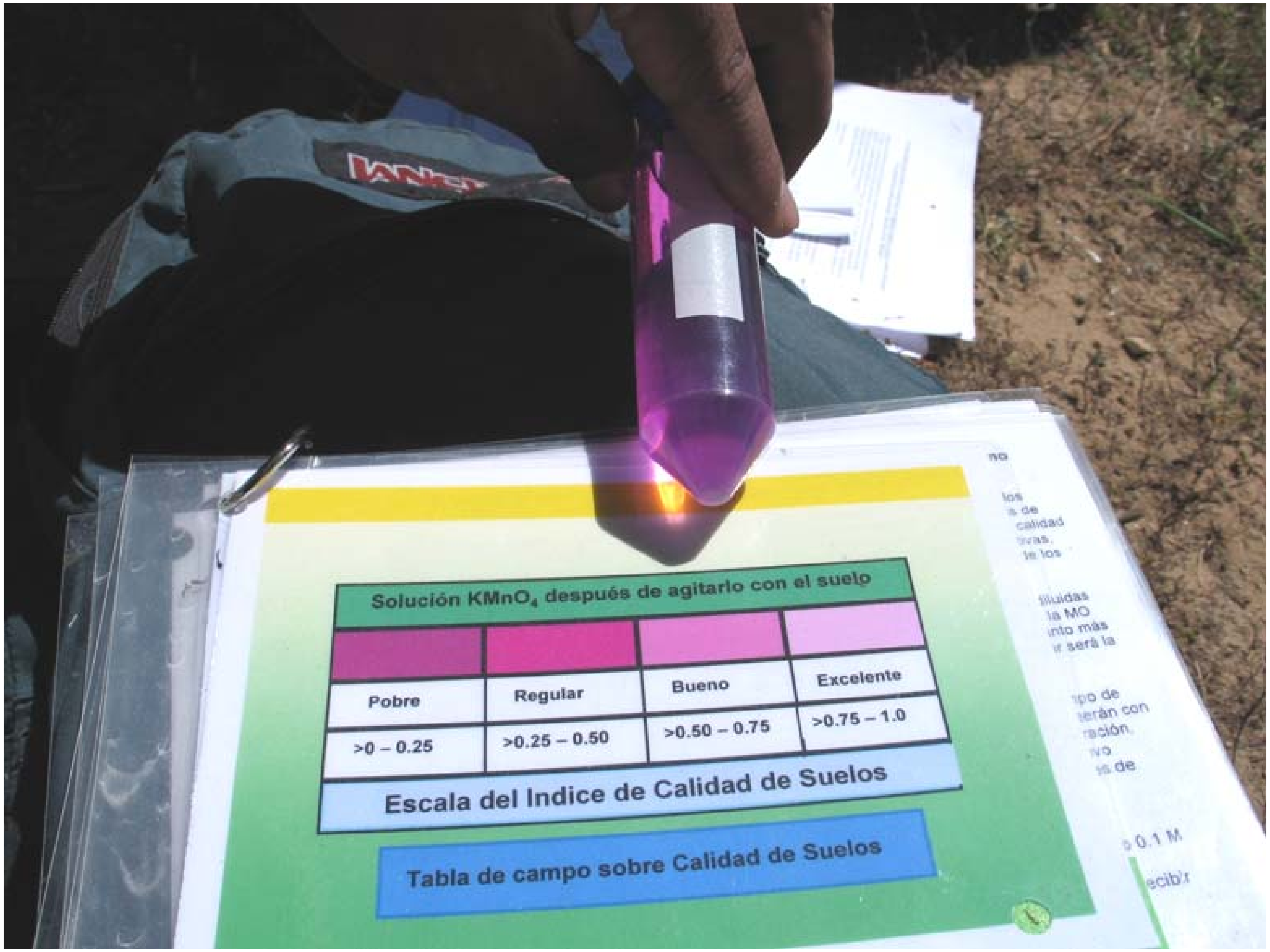
Methodology (cont.)



- $KMnO_4$ can hydrolyze and oxidize simple carbohydrates, amino acids, amine/amide sugar and other C-compounds to give a light – pink color (Skoog and West, 1969;Lefroy et al., 1993).

- Weil, 2003 concluded that the newly developed procedure was more sensitive to management effects and related to soil productivity and soil properties, such as soil respiration, aggregation, better than the procedures based on measurement of total organic carbon.

- **b. Labile C field chart**



Methodology (cont.)

c. a portable field NIR spectrometer

- **Determination of total C using a portable field NIR spectrometer, Fieldspec Pro FR (Stevens et al., 2006)**
- **It may relate to use of remotely sensed infrared imagery to improve diagnostic capabilities to assess plant and soil health.**

Methodology (cont.)

- **H3: Assessing the community perceptions and indicators of soil quality results due to differences in gender, environment and socio-economic factors.**

  Will use participatory workshops:

  - **What is the information on the local soil classification system?**
  - **What are the specific soil quality indicators that community members use to evaluate soil quality among the different soil types and crops?**
  - **How has soil quality changed over time and why?**
  - **The communities will be surveyed to determine the characteristics of a field soil quality testing procedure that would be appropriate for their conditions and for improving sustainable agricultural management.**

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Acknowledgements (con't)

- **"… It is astonishing to me … that they're still only giving me a one page soil test … you need more sophisticated tool than that … this [soil quality index] is great … I'm sure hoping I can get more than one page now … something that I can utilize to manage my soil"**

"Farmers in Central valley of CA"


QUESTIONS
OR COMMENTS?