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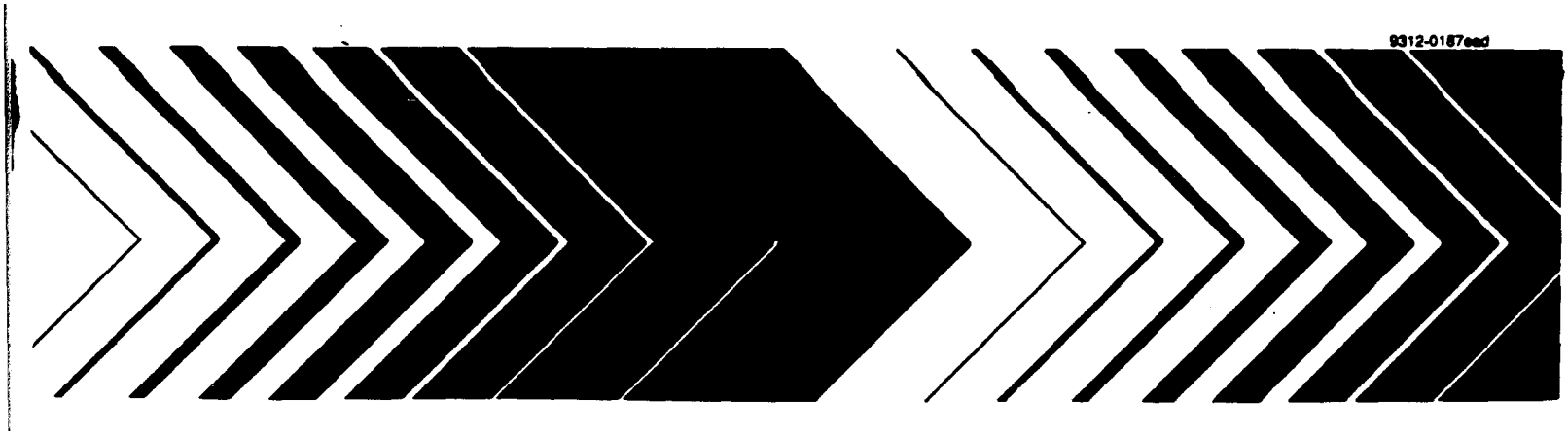
Agroecosystems 1993 Quality Assurance Project Plan

Region VII Pilot Field Program



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ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM AGROECOSYSTEMS 1993 QUALITY ASSURANCE PROJECT PLAN REGION VII PILOT FIELD PROGRAM

by

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QUALITY ASSURANCE PROJECT PLAN APPROVAL

This quality assurance project plan was developed to assure that all environmental data generated for the Agroecosystem component of the Environmental Monitoring and Assessment Program (EMAP) are scientifically valid and of acceptable quality to achieve the research and program objectives established for 1993. Approvals and concurrences represent a commitment to disseminate the plan and the philosophy of total quality to all project personnel.

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ABSTRACT

The Environmental Monitoring and Assessment Program (EMAP) is being implemented to address the need to provide quantitative assessments of the condition of ecological resources within the United States. Within EMAP, Agroecosystems is implementing a pilot field program in U.S. Environmental Protection Agency (USEPA) Region VII, in the State of Nebraska, in calendar year 1993. Field sampling for the Region VII Pilot Field Program is scheduled for mid-October and continue through November, 1993.

This document describes an integrated quality assurance project plan (QAPP) for the pilot field program. The primary purpose of the QAPP is to maximize the probability that environmental data collected during the project will meet or exceed objectives established for data quality. This achievement will allow for scientifically sound interpretations of the data in support of the project goals. The QAPP presents a systematic approach that will be implemented within each major data acquisition component of the Agroecosystems program. Basic requirements specified in the QAPP include: (11 ensuring that field and laboratory collection and measurement procedures are standardized among all participants; (2) monitoring the performance of the various measurement systems being used to maintain statistical control and to provide rapid feedback so that corrective measures can be taken before data quality is compromised; (3) completing a periodic assessment of the performance of these measurement systems and their components; and (41 verifying and validating that reported data are sufficiently representative, unbiased, precise, and complete so as to be suitable for their intended use. These activities will provide data users with information regarding the degree of uncertainty associated with the various data bases developed from the EMAP-Agroecosystems program. This QAPP is prepared following the guidelines and specifications provided by the Quality Assurance Management Staff of the U.S. Environmental Protection Agency - Office of Research and Development.

TABLE OF CONTENTS

1993 Agroecosystems Quality Assurance Project Plan

TABLE OF CONTENTS (cont.)

1993 Agroecosystems Quality Assurance Project Plan

TABLE OF CONTENTS (cont.)

1993 Agroecosystems Quality Assurance Project Plan

FIGURES

TABLES

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Lastly, the author would like to acknowledge the extra efforts of George R. Hess, Michael J. Munster, and Deborah Neher for their effort in preparing the additional requested text dealing with the quality assurance issues specific to their individual indicators. Their extra effort saved the author a great deal of time and eliminated a great many potential errors from my lack of full understanding of the work

ACRONYMS

ARG	**Agroecosystem Resource Group**
ARS	**Agriculture Research Service**
AWC	**available water content**
B	**bias (net)**
CC	**calibration check**
CEC	**cation exchange capacity**
CV	**coefficient of variation**
DO0	**data quality objective**
DR	**detection reference**
EMAP	**Environmental Monitoring and Assessment Program**
FD	**field duplicate**
FS	**field split**
IPM	**integrated pest management**
JES	**June Enumerative Survey**
LD	**laboratory duplicate**
MDL	**method detection limit**
MI	**maturity index**
MQO	**measurement quality objective**
NASS	**National Agricultural Statistics Service**
NCSU	**North Carolina State University, Raleigh, North Carolina**
PLD	**preparation laboratory duplicate**
PO	**project officer**
PPI	**plant-parasitic index**
PSU	**primary sampling unit**
QA	**quality assurance**
QAC	**quality- assurance coordinator**
QAM	**quality assurance manager**
QAPP	**quality assurance project plan**
QC	**quality control**
QMP	**quality management plan**
RB	**reagent blank**
RPD	**relative percent difference**
RS	**reference sample**
RSD	**relative standard deviation**
S&E	**supervising and editing**
SCS	**Soil Conservation Service**
S	**standard deviation**
SOP	**standard operating procedure**
SSSD	**State Soil Survey Database**
T	**tolerance factor (related to soil erosion)**
TD	**technical director**
TSA	**technical systems audit**
TV	**theoretical value**
UPS	**United Parcel Service**
USDA	**United States Department of Agriculture**
USEPA	**United States Environmental Protection Agency**

Section 1
Introduction

The U.S. Environmental Protection Agency USEPA), in collaboration with other federal agencies, research institutes, and university systems, has initiated the Environmental Monitoring and Assessment Program (EMAP) to develop a long-term approach to assess and periodically document the condition of ecological resources at the regional and national scales and to develop innovative methods for anticipating emerging problems before they reach crisis proportions. This program responds to the growing awareness of regional and global-scale environmental degradation. The goals of EMAP are to monitor and assess the condition of U.S. ecological resources and to contribute to decisions on environmental protection and management.

To achieve these goals, EMAP will:

1. **estimate the current status, trends, and changes in selected indicators of the condition of the Nation*s ecological resources on a regional basis with known statistical confidence,**

2. **estimate the geographic coverage and extent of the Nation*s ecological resources with known statistical confidence,**

3. **seek associations between selected indicators of natural and anthropogenic stresses and indicators of condition of ecological resources, and**

4. **provide annual statistical summaries and periodic assessments of the Nation*s ecological resources.**

The EMAP efforts are focused on linking existing environmental monitoring programs, where possible, and collecting new information as needed to achieve program objectives. EMAP is not intended as a substitute for ongoing programs but will likely enhance the value of local monitoring results by placing them in the perspective of a larger geographical context.

The overall sampling design developed to meet the EMAP program goals is a systematic triangular grid of points extended across the nation, with approximately 27.1 km between nearest neighbor points. Each point serves as a possible location for collecting samples of ecological resources. The systematic grid design facilitates a survey of any well-defined and spatially distributed resource. Specifically, the EMAP sample grid identifies approximately 12,200 hexagons that cover the conterminous 48 states of the United States, each of which has an area of approximately 650 square kilometers. The selected 12,600 points also define the centroids of smaller hexagons of approximately 40.6 square kilometers, such that each large hexagon contains 16 smaller hexagons. A random positioning of the systematic grid establishes the EMAP systematic sample as the probability sample necessary to make statistical estimates of status and condition with known confidence. Information about resources is obtained from areas surrounding the systematic grid points. The overall EMAP sampling design is described in detail by Over-ton et al. (1990) and by White et al., (1992).

To accomplish its goals and objectives, EMAP has established seven ecosystem monitoring and research groups, namely, Estuaries, Great Lakes, Surface Waters, Forests, Agroecosystems, Arid Ecosystems, and Landscape Ecology. Each resource group (an interdisciplinary group of scientists) has been tasked to develop strategies for the collection, analysis, and integration of data from each of their ecological resources. Additionally, seven cross-system program groups (i.e., Design and Statistics, Quality Assurance, Information Management, Landscape Characterization, Indicators, Methods and Logistics, and Assessment and Reporting) have been established to assist resource groups and to ensure total quality management, consistency, and integration across the EMAP program.

More complete information about the overall EMAP program is provided in the *Environmental Monitoring and Assessment Program Guide* (Thorton et al., 19931 and in the *Environmental Monitoring and Assessment Program: Master Glossary* (EMAP, 1993).

1. 1 Overview of the Agroecosystem Program

This section provides a brief overview of the Agroecosystem component of the EMAP program. A more detailed description of the program is provided in *Environmental Monitoring and*

Assessment Program (EMAP) - Agroecosystem Monitoring and Research Strategy (Heck et al., 1991) and the *Agroecosystem Pilot Field Program Plan* - 1993 (Campbell et al., in prep.).

1. 7.7 Establishment and Mission

In 1988, an Agroecosystem Resource Group (ARG) was established to oversee, define, and conduct the operations of the Agroecosystem component of the EMAP program. The ARG was originally established with Roy E. Cameron (Lockheed Environmental Systems & Technology Company, Las Vegas, NV) as Acting Technical Director (TD). Walter W. Heck (U.S. Department of Agriculture - Agriculture Research Service [USDA-ARS]) was TD from 1989 through 1992 and currently serves as Associate Director of EMAP Terrestrial Systems. C. Lee Campbell of the USDA-ARS currently serves as the EMAP Agroecosystem TD.

The mission of the ARG is "to develop and implement a program to monitor and evaluate the long-term status and trends of the nation*s agricultural resources from an ecological perspective through an integrated, interagency process" (Heck et al., 1991 l. To accomplish the mission, various developmental stages are required to establish and test various parameters (indicators) that are believed to be indicative of the "health" of the agroecosystem. The first developmental stage of the EMAP Agroecosystem program included the 1992 Pilot Field Program conducted in USEPA Region IV (North Carolina). The second stage is to conduct the 1993 Pilot Field Program in USEPA Region VII (Nebraska) for which this quality assurance project plan (QAPP) is being prepared. Additional regional pilot and demonstration field programs will be conducted to allow for the orderly attainment of full national implementation while assuring the essential scientific rigor.

1.1.2 Definition and Importance

Agroecosystems, as defined for EMAP, are *"dynamic associations of crops, pastures, livestock, other flora and fauna, atmosphere, soils, and water. Agroecosystems are contained within larger landscapes that include uncultivated land, drainage networks, rural communities, and wildlife* (Campbell et

Agroecosystems have perhaps the greatest impact on our daily lives of any of the terrestrial ecosystems because they provide food and fiber and have a large influence on the quality of the environment. Globally, agriculture accounts for nearly 20% of the terrestrial net primary productivity and approximately 30% of the land area (Coleman and Hendrix, 1988). In the United States, crop land accounts for approximately 179 million hectares, nearly 20% of the total U.S. land area (U.S. Dept. of Commerce-Bureau of the Census, 1990). Total farm land in the U.S. comprises nearly 386 million hectares or about 43% of the total U.S. land area.

Agriculture is a major component of the U.S. economy. The production, processing, and sale of food and fiber account for approximately 17.5% of the gross national product or approximately $700 billion in economic activity annually (National Resource Council, 19891. The indirect socioeconomic effects of agriculture are equally significant when the impact of farms and farm-related businesses on the well-being of rural and urban communities are considered.

1.7.3 Objectives

The objectives of the EMAP ARG parallel those established for EMAP. When fully implemented, the program will meet the following objectives related specifically to agroecosystems:

1. estimate the current status, trends, and changes in selected indicators of the condition of the Nation*s agroecological resources on a regional basis with known statistical confidence,

2. estimate the geographic coverage and extent of the Nation*s agroecological resources with known statistical confidence,

3. seek associations between selected indicators of natural and anthropogenic stresses and indicators of the condition of agroecological resources,

4. provide annual statistical summaries and periodic assessments of the Nation*s agroecological resources, and

5. identify and assess common indicators that are valid and usable across EMAP Resource Groups, in particular, the terrestrial Resource Groups.

The ARG recognizes that the sustainability of agroecosystems is of primary importance to the people of the United States and the world. Ecological sustainability of agroecosystems is the principal focus for the Agroecosystem monitoring effort and is defined as the ability to maintain or enhance over the long term: quality of air, water, and soil; productivity; and biodiversity within and of surrounding ecosystems. These components of ecological sustainability are defined in relation to people and society and are thus, referred to as "societal values". These societal values parallel the "assessment endpoints" presented in the *Agroecosystem Monitoring and Research Strategy* plan (Heck et al., 1991). These values will also serve as a focus for development of the overall strategy for agroecosystem monitoring and for the selection of specific biotic and abiotic indicators of ecological condition of the resource.

1.2 Quality Assurance Program

The potential temporal and geographic scope of EMAP is immense as compared to most existing environmental monitoring programs. In addition, EMAP information eventually will be used in conducting risk assessments that are integrated across ecological resource types. To provide information that is of sufficient quality (and thus usefulness) to address the program*s objectives, a comprehensive and integrated quality assurance (CIA) program is required for both the Agroecosystems component of EMAP and for EMAP as a whole.

As part of the USEPA*s Office of Research and Development, EMAP will participate in the Agency*s mandatory QA program (Stanley and Verner, 1985). The overall policies, organization objectives, and functional responsibilities associated with the EMAP QA program are documented in the Quality Management Plan (QMP; Kirkland, in prep.). The QMP currently specifies that QA will be integral to all data acquisition activities conducted as part of EMAP. All ecosystem resource groups will develop appropriate QA programs to ensure resultant data and information are of known, adequate, and documented quality.

The QA policy of the USEPA (Stanley and Venter, 1985) requires that every monitoring and measurement project have a written and approved QAPP. This requirement applies to all environmental monitoring and measurement efforts authorized or supported by the USEPA through regulations, grants, contracts, or other formal means. Four categories of QA levels of effort have been described by the USEPA Risk Reduction Engineering Laboratory (Simes, 1989) and the EMAP QMP (Kirkland, in prep.). The QAPP for 1993 Agroecosystem Pilot Field Program falls into a Category III project. The QMP describes a Category III project as:

> Projects that *"Include pilot projects incorporating environmental data operations performed as interim steps in a larger group of operations. Such projects include those producing results that are used to evaluate and select options for interim decisions, such as selection of core indicators for regional demonstration projects or to perform preliminary assessments of unexplored areas for future work such as sampling design aspects".*

This QAPP has been prepared as part of the QA program that is being implemented by EMAP Agroecosystem program. This QAPP documents the process for achieving the level of data quality required by users of the data collected by the EMAP-ARG. The recommended elements for organization and content of a Category III QAPP (Simes, 19891 are included and addressed in this QAPP.

1.2.1 Quality Assurance Project Plan for Agroecosystems - 1993

A description of the EMAP-Agroecosystem Pilot Field Program, project organization and responsibilities, indicator status, and site selection are given in Section 2. Quality assurance objectives are discussed in Section 3. Quality assurance procedures and criteria for assessing data quality are given for each of the three indicators in Section 4. The first subsections in Section 4 address QA components that apply to each of the indicators; the subsequent subsections address QA issues related to specific indicators.

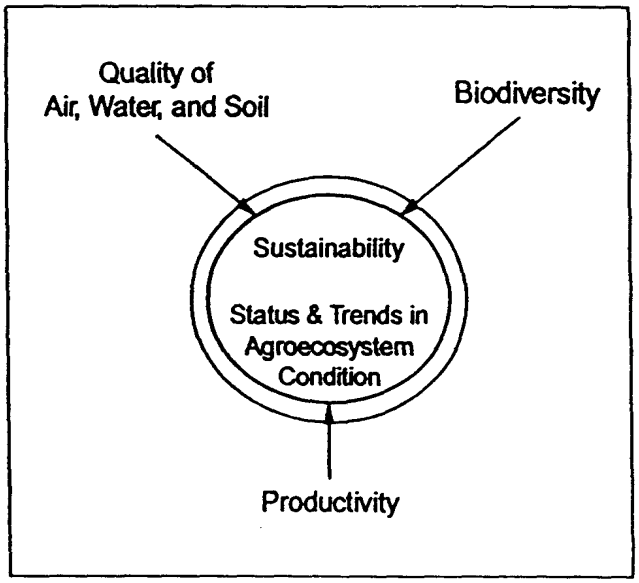
This QAPP is applicable to field and laboratory data acquisition and interpretation activities that will be conducted by the EMAP-Agroecosystem program between October 1993 and July 1994. Field operations for these activities will be conducted in October and November (post

harvest), 1993. Laboratory operation and data analysis and interpretation activities will be conducted through the winter of 1993 and spring of 1994. The QAPP will be revised, when appropriate, as additional data acquisition activities are identified by the EMAP-Agroecosystem Resource Group. It is anticipated that this document will undergo a revision annually. This version will be designated as Revision 1.0. Any minor revisions to the document between now and the next major revision will be tracked in the document control format (i.e., the header information placed on the upper right-hand corner of each page) and will be numbered 1.1, 1.2, etc.

Section 2
Project Description

The goal of the EMAP-Agroecosystem program is to assess the long-term status and trends in the condition of the Nation*s agroecosystems from an ecological perspective. Ecological sustainability of agroecosystems is the principal concern in this assessment. However, agroecosystem condition and sustainability cannot be measured directly; such measurement requires information related to the three societal values: quality of air, water, and soil; productivity; and biodiversity Fig. 2.1).

Figure 2.1. Societal values considered in the monitoring of agroecosystems.



2.1 Sustainability

The ARG recognizes that sustainability of agriculture is of primary importance to the people of the United States and the world. There are three aspects of sustainability, which can be judged on different scales as follows:

An agroecosystem is *ecologically sustainable* if it maintains or enhances its own long-term productivity and biodiversity, the biodiversity of surrounding ecosystems, and the quality of air, water, and soil.

A farm is *economically sustainable* if it is economically viable over the long-term.

An agricultural system is *socially sustainable* if it meets the basic food and fiber needs of society and maintains or enhances the quality of life for farmers and society.

EMAP-ARG is only interested primarily in the ecological sustainability of agroecosystems; nonetheless, EMAP-ARG recognizes that information developed by it may be valuable in the assessment of the condition of multiple ecological resources and in promoting the other dimensions of sustainability discussed here.

2.2 Societal Values

Three societal values are the primary components of ecological sustainability. These values are:

- **Quality of Air, Water, and Soil: the physical and chemical condition of these natural resources.**

  Agroecosystem performance is a function of the quality of the air, water, and soil entering and within the agroecosystem. In addition, agriculture can affect surrounding air, water, and soil.

- **Productivity: the ability to provide food and fiber for human uses.**

  The continued ability of agroecosystems to produce food and fiber is clearly of interest to society. This ability involves both productive capacity and efficiency of an agroecosystem.

- Biodiversity: the variety of life and of the ecological complexes in which it occurs.

Diversity of some species in the agroecosystem, including pollinators and insect predators, can positively affect productivity, while diversity of others, such as pests, can have negative effects. Genetic diversity is important as the raw material for improved crops and livestock and in the prevention of devastating epidemics. In addition, agriculture can affect biodiversity in the surrounding landscape.

2.3 Assessment Questions for the 1993 Agroecosystem Pilot Program

By focusing on specific aspects of the three societal values, assessment questions form the link between these values and indicators (Campbell et al., in prep). They guide the integration of data from agroecosystems into more general information about the three societal values and sustainability over the region. The list of assessment questions for the Agroecosystem monitoring program is presented in Table 2.1.

2.4 EMAP-Agroecosystem Indicator Strategy

Assessment questions can be addressed with information derived from indicators, which are measures of the environment that reflect the condition of an ecological resource or its exposure to stress. In the EMAP-Agroecosystem program, two types of indicators are recognized: condition indicators and stressor indicators.

A condition indicator is a characteristic of the environment that reflects the condition of an ecological resource. A biotic condition indicator reflects the condition of the biotic component of the resource and an abiotic condition indicator reflects the condition of the physical or chemical component of the resource. A stressor indicator is a characteristic of the environment that is believed to affect the condition of the resource.

Table 2.1. Societal Values and Related Assessment Questions.

Societal Value	Assessment Questions
Quality of Air, Water, and Soil	◦ What proportion of agroecosystems has soil quality sufficient to sustain productivity (crop and non-crop)?
Productivity	◦ What proportion of agroecosystems is attaining their productive capacity (as determined by soil type, land capability class, historic yields, etc.)? ◦ What proportion of agroecosystems display acceptable production efficiency for crops?
Biodiversity	◦ What proportion of agroecosystems has associated noncrop areas with habitat suitable for wildlife species of interest? ◦ What proportion of agroecosystems has acceptable diversity of soil microbes and invertebrates? ◦ What proportion of agroecosystems has acceptable insect diversity? ◦ In what proportion of agroecosystems is diversity of wildlife declining?

An initial list of fifteen indicators has been identified for possible use in the Agroecosystem monitoring program (Table 2.2). However, due to fiscal and logistic limitations, it may not be possible to retain all of the indicators within the regional and national monitoring program. Therefore, a shortened list of indicators was selected for testing and development by the ARG.

2.5 Selection of Indicators for the 1993 Plot Field Program

Indicator selection for the 1993 Pilot Field Program was based on the likelihood of success in collecting and interpreting data. Criteria for judging this likelihood were: 1) the ability of National Agricultural Statistics Service (NASS) enumerators to collect the required survey data and samples, 2) the availability of analytical and assay procedures that fit within the quality assurance, quality

control, and fiscal standards of the ARG, 3) the ability of the ARG to use and interpret the data obtained, and 4) experience from the 1992 pilot.

The first criterion is essential because one goal of the 1993 Pilot is to refine the relationship established between the ARG and NASS in 1992. The ARG still plans for NASS enumerators to serve as the primary grower contacts and as the primary field personnel for acquiring specific samples (e.g., soil, water). In this pilot, it is essential to confirm this relationship as a viable approach.

The second criterion reflects the challenge to the ARG of assembling a suite of indicators that will answer the assessment questions, is scientifically credible and informative, and meets budget constraints.

The third criterion acknowledges the difficulty of combining and interpreting data from diverse sources. From the perspective of the Design and Statistics component of the pilot, indicators need to have a relatively clear, known interpretation with manageable variability within and among sample units.

The fourth criterion acknowledges the aid that prior experience provides in judging the suitability of specific measurements or indicators.

2.6 Indicators Selected for the 1993 Pilot Field Program

Based upon the four criteria identified in Section 2.5, four candidate indicators have been selected for use in the 1993 Pilot Field Program:

- Crop Productivity,
- Soil Quality,
- Land Use and Cover, and
- Pest Management (including Agricultural Chemical Use).

Table 2.2. Association Between Agroecosystem indicators and Societal Values.

Indicator	Quality of Air, Water, and Soil	Productivity	Biodiversity
Soil Quality: Physical/Chemical	X	X	
Soil Biotic Diversity (Nematode indices)	X	X	X
Crop Productivity		X	
Land Use and Cover		X	X
Pest Management (including Agrichemical Use)	X	X	X
Water Quality: Ponds and Existing Wells	X	X	X
Landscape Structure	X		X
Biological Ozone Indicator (Clones of white clover)	X	X	X
Insect Diversity		X	X
Groundwater/Well Comparisons	X	X	
Socioeconomic Health	X	X	
Habitat Quality	X		X
Symptoms of Foliar Injury	X	X	
Genetic Diversity		X	X
Livestock Productivity		X	

One additional research indicator, namely, soil biotic diversity (as measured by nematode community structure in soil) will be evaluated in the 1993 Field Pilot Program.

All three societal values are addressed by this group of indicators. The specific values addressed by each indicator were identified in Table 2.2.

2.7 1993 Field Pilot Program

USEPA Region VII and the State of Nebraska were selected for the 1993 Pilot Field Program for several reasons, given in order of importance:

1. **The physiographic diversity of the state is representative of typical midwestern agroecosystems (intensively cropped areas) and of western agroecosystems (sparsely cropped areas); the state contains a transition zone between these types of agroecosystems; and the state contains an area (Platte River Basin) where intensively managed agroecosystems intrude into an area of non-intensively managed systems.**

2. **Nebraska contains a transition between agroecosystems and arid ecosystems, which will allow for the careful definition of the areas of responsibility, as well as areas of opportunity for sharing of responsibility, between the ARG and the Arid Ecosystems Resource Group.**

3. **EPA Region VII expressed strong interest in the Agroecosystem monitoring program.**

2.8 Objectives

The 1993 Pilot Field Program is designed to provide information that will allow for the evaluation of specific aspects of the Agroecosystem monitoring program. There are four major objectives as follows:

1. **Empirically evaluate an initial suite of indicators to:**
   - **o evaluate the ability of an indicator to address the assessment questions and societal values of interest,**
   - **o establish an initial range of values and variance for each indicator across a midwestern region,**
   - **o assess components of variability of indicators within and among sample units,**

- o identify the usefulness and sensitivity of each indicator in determining ecological condition, and
- o determine the cost-effectiveness for each indicator.
- o identify commonality among parameters for potential use across EMAP terrestrial Resource Groups.

2. Compare the relative efficiency, in terms of cost and precision, of the EMAP Hexagon Design and the NASS Rotational Panel Design for use in a national agroecosystem monitoring program.

3. Develop and refine plans for key components of the monitoring program, including:
   - o sampling,
   - o logistics,
   - o total quality management (including quality assurance and quality control),
   - o data analysis, summarization, and reporting, and
   - o information management.

4. Develop and evaluate additional measurements that will address specific indicators, including:
   - o soil quality - biological component and
   - o landscape structure.

Section 3
Sampling Design

The 1993 EMAP-Agroecosystem Pilot Field Program will provide a second comparison of the EMAP hexagon sampling plan and the NASS rotational panel sampling plan on an area with very different physiography and cropping regimes from that found in the North Carolina 1992 Pilot. Both cost and precision will be considered in evaluating the relative efficiencies of the two sampling plans in obtaining the required information necessary for the EMAP-Agroecosystem program.

Both sampling plans under consideration use the NASS Area Frame segments as the basic sampling units (Heck et al., 1991). The NASS area frame segments are defined by first stratifying the state of Nebraska based on amount (generally by percent area cultivated) of agriculture. Each stratum is divided into Primary Sampling Units (PSUs). A random sample of the PSUs is then divided into six to eight sample segments, with segment size dependent on strata. For example, segment size is approximately 0.1 square mile for urban strata, 1 square mile for agricultural strata, and 4 square miles for rangeland strata.

Specifics of each sampling plan as they relate to site selection for sampling is presented in the following sections.

3.7 The Hexagon Sampling Man

There are 317 EMAP hexagons (40, km*) with their centroids within the Nebraska state boundaries that were eligible for selection as 1993 Pilot hexagon samples. These hexagons were divided into four interpenetrating replicates according to procedures outlined in the EMAP Design Report (Overton et al., 1990) where specific replicates are to be used in particular years. The designated 1993 EMAP replicates were selected for the 1993 Pilot. This selection process resulted in the identification of 77 hexagons for sampling which are located in 58 of the 93 counties in Nebraska.

The coordinates of the centroids of these 77 hexagons were forwarded to NASS for identification of the NASS sample segments according to the following procedures:

1. The PSU that surrounds the centroid is identified along with its IO number, i.e., stratum, substratum, county, and NASS replicate. A NASS technician will divide the PSU into segments according to NASS*s standard criteria. Special care will be taken to ensure that the technician does m know the location of the centroid within the PSU to avoid bias while delineating the segment boundaries.

2. After segments within the selected PSU have been delineated, the segment containing the centroid is identified and designated as a sample segment.

3. Characteristics described at the time of segmentation include the area of the PSU, the area of the selected segment and, if possible, the estimated cultivated acreage and an estimate of the number of fields within the segment.

4. The boundaries of the PSU and the selected segment are delineated on an aerial photo and on a county highway map for use by NASS field staff and the enumerators during data collection. Duplicate photos and maps may be prepared for the ARG in accordance with the NASS confidentiality guidelines.

Nearly half of Nebraska is covered by rangeland that, agriculturally, is used primarily for grazing livestock and from which some wild hay is harvested. These areas are minimally managed. Of the 77 hexagons selected for the 1993 pilot, 37 are located within rangelands. It is expected that the EMAP Hexagon sample segment in these rangeland areas will have limited cropped acreage. All segments identified by the 77 hexagon centroids are included in the sample regardless of whether they fall in rangeland areas. All agricultural fields identified in all segments, despite the predominant nature of the landscape, are included in the list of fields for selection.

3.2 The NASS Rotational Panel Sampling Plan

The complete 1993 NASS sample, from their June Enumerative Survey (JES), in Nebraska has 390 segments in 7 different strata (Campbell et al, in prep). Three NASS replicate years will be used in the 1993 Nebraska Pilot. Replicate years 1, 3, and 5 of the NASS 1993 JES sample, where the number represents the number of years that the replication has been in the rotation, will be used to select the NASS Rotational Panel Plan samples. These replicates were chosen because they represent the full range of time sample units are in the NASS rotation. The newest replication provides a direct comparison with the EMAP Hexagon Plan since both the newest replication (year 1) in the NASS Rotational Panel Plan and the EMAP Hexagon Plan will have approximately the same expected number of fields and the segments within each of the plans will be visited for the first time by NASS enumerators during the 1993 Nebraska Pilot. This will allow the Rotational Panel and Hexagon, designs to be more comparable with respect to the interview conducted during the JES. In addition, use of sample segments from the three replicate years may provide for an evaluation of the effects of the length of time the segment has been selected as a sample.

Maps and aerial photos will be prepared for the Nebraska NASS Field Office for each of the 390 NASS sample segments in the 1993 JES. For many NASS segments in Nebraska, county highway maps are used instead of aerial photography. Duplicate aerial photographs or maps of the segments selected from the 1993 pilot will be sent to the ARG.

3.3 Within Segment Sampling Protocols

Most of the indicators for EMAP-Agroecosystem in the 1993 Pilot Field Program will be determined either on individual fields (e.g., fertilizer and pesticide applications) or on a random small area within the field (nematode assay and soil properties). Field sampling protocols will be divided into two parts: (1) selecting fields within the segments and (2) sampling within those fields. The field selection procedure and field sampling protocols are the same for both the EMAP Hexagon Sampling Plan and the NASS Rotational Panel Sampling Plan.

3.3.1 Field Selection

The field identification and acreage data taken in the JES will be used to randomly select a subset of fields over all selected segments in the EMAP Hexagon Plan and, separately, over all segments within rotation years 1, 3, and 5 for the NASS Rotational Panel Plan. All fields that contain crops that have not been excluded from the 1993 (see below) Pilot will be included in the ordering.

Selection of fields is based on selection of random "acres" from the total expanded cropland acres contained in the sample of segments. During the JES, NASS enumerators obtained land use information on all areas of each sample segment. The location of each cultivated field in each sample segment will be mapped on an aerial photograph or a county highway map and its identification number and acreage recorded. For the 1993 Pilot, the population of eligible fields will contain a single resource class, defined as the planted acreage in any field that contains annually harvested herbaceous crops. Fields in summer fallow will be included. The agroecosystem resource classes that are not being considered for inclusion in the study are: perennial fruit and nut crops; permanent managed pastures; windbreaks; farm ponds; and other agricultural lands including farmsteads, ditches, farm roads, grass waterways, confined feed operations, and woodlots. These were excluded largely because condition indicators for these resource classes have not reached a state of development where they are ready to be pilot tested.

A more complete description, including statistical considerations, of how a particular segment is selected for sampling is presented in the *EMAP-Agroecosystem 1993 Pilot Field Program* (Campbell .et al, in prep).

3.3.2 Sampling Within Fields

Soil sampling to determine soil physical and chemical properties and nematode densities will require within field sampling. Soil samples will be collected by both the NASS enumerators and the USDA-Soil Conservation Service (SCSI soil scientists. NASS enumerators will collect a composite sample from 20 soil cores of the top 20 cm in each field. This composited sample will provide

contrast, the SCS will collect individual, non-composited, soil samples based on soil horizons identified in a pit dug (approximately 51-cm deep) at each site. Each SCS sample (up to 4 samples per pit) will be collected and analyzed as individual samples for a series of routine parameters and several .special" properties. These 'special* properties (e.g., bulk density) can not be obtained from the soil samples collected by the NASS enumerators. Specialized training are required for the sample. The manner in which the NASS enumerator collects the sample destroys the soil structure. A more detailed description/discussion of the sampling procedures to be used by both organizations is presented in the following sections.

3.3.2.1 NASS Soil Sampling

The protocol for the NASS soil sampling is the same as used in the 1992 North Carolina Pilot (see Appendix A). Each NASS enumerator is provided a copy of the soil sampling protocols during the field training session held October 13 and 14, 1993 in Lincoln, NE.

For each field, the NASS enumerator will be given the following information printed on an instruction sheet placed within their questionnaire: the sample number(s), whether or not a second composite sample must be collected* in that field, the number of cores to be collected from each transect, and the number of paces along and into the fold to determine the midpoint of the sampling transect. Two labels, each with a different identification number, will be provided for composite samples that will be divided into field duplicate samples. All labels will be printed in cooperation with the Nebraska State Office of NASS. The sampling design was constructed to include measures of within-field variability (a second field duplicate sample collected in every sixth field) and within-sample variability (field split samples taken from the second composite sample from every twelfth field).

Twenty cores (2-cm diameter and 20-cm in length) of soil are necessary to provide enough soil (approximately 1256 cm^3) for the required analyses on routine samples. Total soil volume of each composite sample must exceed 1000 cm^3, half of which is required for chemical/physical analysis and the other half for nematode enumeration. When a field is selected for a field split sample, 40 cores per transect will be required to collect enough soil for all laboratory determinations.

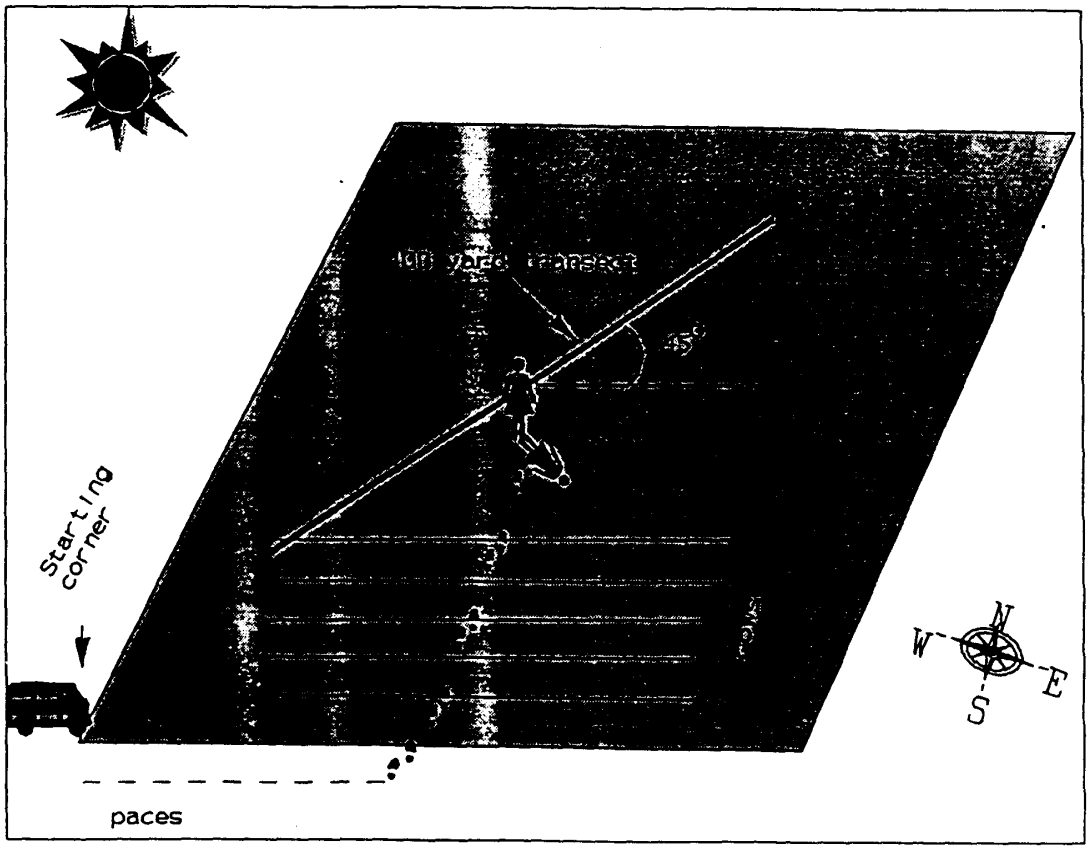
Within each routine field, one core will be taken at each of 20 locations (selection criterion for the 20 core locations to be discussed), except for field split samples where two cores will be taken at each of 20 locations, equally spaced along a 100 meter diagonal transect. For each core, the soil tube will be pushed *straight* down into the soil, without twisting, to the depth that fills the length of the tube (20 cm). The tube will be pulled up and the soil core placed into a plastic bucket. If the core is unsatisfactory (i.e., It contains less than 4 inches of soil), another core will be taken in the same location within a 15 cm radius of the original position. When all 20 cores have been deposited into the bucket, the enumerators will mix the soil thoroughly by hand, breaking up soil clumps *gently*. [NOTE: A preliminary study indicated variability associated with subsampling of composite samples that were hand mixed was not significantly different than for those mixed with a riffle sampler.] Any rocks greater than 2 cm in diameter will be discarded in the field, but all surface organic matter should be kept as part of the soil sample. When appropriate, soil for nematode enumeration will be subsampled from the mixed composite sample prior to collection of the sample for physical and chemical analyses. In the case when a field split sample (every twelfth field) is to be collected, both nematode samples should be collected prior to the splitting of the remaining soil into the two field split samples for physical and chemical analysis.

Collected samples will be placed in plastic bags closed by a paper-wire tag and then enveloped in a pre-addressed padded mailing container and stored in an insulated container (ice chest). Samples will be shipped directly to the analytical laboratory the same day they are collected or first thing the next morning through Federal Express (1-800-235-5355 for pick-up) or United Parcel Service (UPS) express service. Postage will be paid u&g a Federal Government account through the Air Resources Research Consortium at North Carolina State University.

To determine the location for the collection of an individual core sample and to set up the transect used during sample collection, a stating point will be located in the field based on a random number of rows and paces along rows from any field comer. If no definite field corners are identifiable, then the stating point should be the point most accessible by car. The NASS enumerator will select two random numbers from a random number chart to represent the number of rows and paces, respectively, the enumerator must take to identify the mid-point of the sampling transect. If rows are not present in the field, random paces will be used. At the transect mid-point, the transect will run at a 45^0 angle to the direction being walked by the enumerator

(Fig. 3.1). From the mid-point on the transect, the enumerator will take 20 soil cores in each direction along the transect with the first core being 1.75 meters from the center point and each succeeding core being an additional 2.5 meters away. For example, if the enumerator had come to the selected point from due south, then the transect would run from the center point approximately 50 meters to the northeast and 50 meters to the southwest.

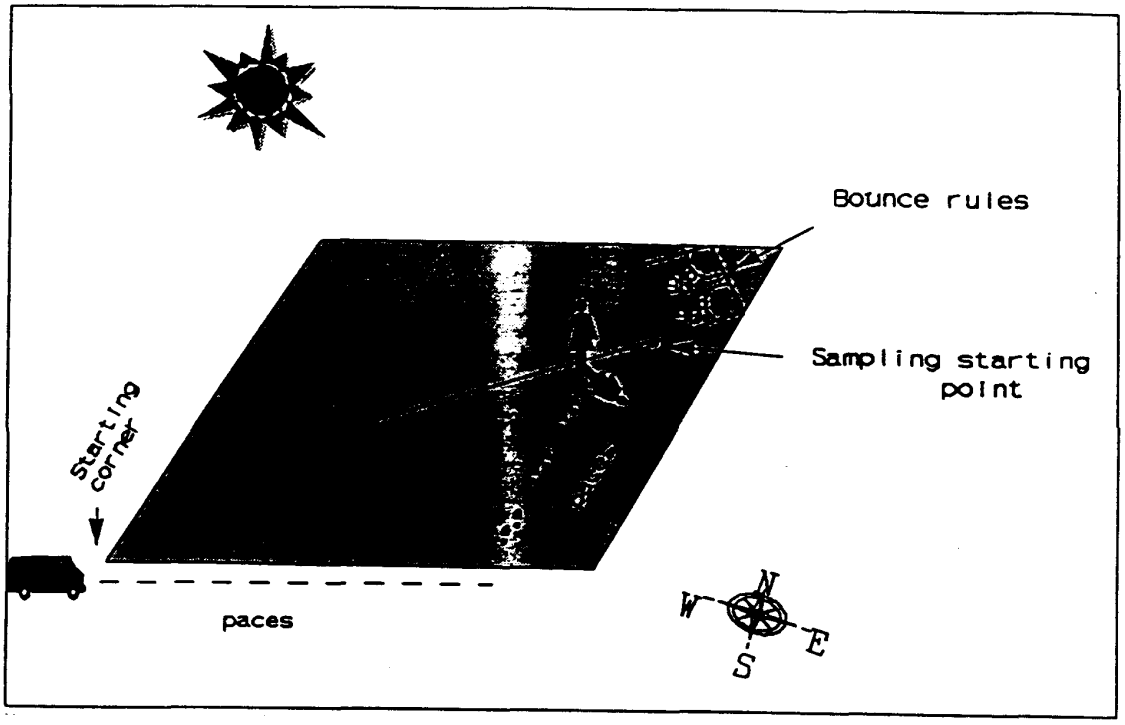
Figure 3.1. Transect sampling of field.



If the transect intersects the boundary of a field then a set of "bounce" rules will be initiated. Upon reaching the field margin, the enumerator will reflect off the boundary at an angle of 90 degrees from the direction of the transect (Fig. 3.2). The NASS enumerator will turn into the field

during the 90 degree bounce. This will continue for every boundary encountered until the entire distance (100 meters) of the transect has been traversed.

Figure 3.2. Transect sampling of field (Bounce rules).



To ensure that the sampling is not biased by the subjective selection of the sampling location, the NASS enumerators will mark the end of each 5-pace (approximately 2.5 n$ interval with a wooden stake and, before sampling, will lay a marked stick along the transect at the stake. The soil core sample will then be taken at either 46 cm (1.5 feet) or 91 cm (3 feet) from the stake, depending on whether the stake is odd or even from the end of the transect from which the sampling was initiated.

On every sixth field, when a field duplicate sample must be taken, the NASS enumerator will follow the same procedures just discussed but will start at a different field corner.

On every twelfth field, when a field split sample must be collected, the NASS enumerator will collect an additional 20 core samples in the second transect (i.e., a total of 40 core samples will be collected and composited for that transect). The additional core sample will be collected within a 15 cm radius from the First core sample at each of the 20 marked sampling locations.

Other situations, such as odd-shaped fields and when field edges are encountered during the laying out of the transect, are discussed in detail in Appendix A.

3.3.2.2 SCS Soil Sampling

SCS soil scientists will visit approximately 36 of the sample fields (chosen from the EMAP hexagon identified fields). The additional samples are collected by the SCS for two primary purposes within the ARG. These purposes are:

1) to allow for the determination of "special" soil parameters (e.g., bulk density and aggregate stability) that are being examined to determine their potential as indicators of the soil*s "physical health* [NOTE: the "special" soil parameters can not be determined on the NASS-collected composite samples], and

2) to allow for a comparison of results between the composite samples collected by NASS and the horizon-based samples collected by the SCS.

The SCS will describe and sample fields that have previously been sampled by the NASS enumerators. At each field, the SCS samplers will determine the soil map unit composition of the field, the map unit(s) crossed by the NASS transect described above, and the class(es) of accelerated erosion on the field (see Appendix 6 for soil erosional classes and identification criteria). A more detailed protocol for soil sampling by the SCS is provided in Appendix B. Additional information on the sampling requirements and methods of the SCS may be found in the *National Soils Handbook* (USDA-SCS, 1983).

Once the map units have been identified, the SCS samplers will dig a 51 cm (20 inch) deep pit on each map unit that is crossed by the transect. If only one map unit is identified in the

transect, then only one pit will be dug and sampled. No more than two pits will be dug on any given transect. If more than two map units are identified in a transect, the SCS will sample the two dominant soil components only. At each pit, the SCS soil sampler will describe the soil and site characteristics following their standard procedures identified in the Soil Survey *Manual* (USDA-SCS, 1951). Standard form SCS-SOI-232 will be used to record all the appropriate site and soil information using the standard SCS coding system. Examples of the forms and characteristics described at each pit are presented in Appendix C.

Upon completion of the site and pit description, approximately 3 to 5 kg samples will be collected from each soil horizon. Samples from up to four soil horizons will be collected for determination of the same analytical parameters (to be discussed) as the samples collected by NASS and for additional soil physical properties (i.e., "special" soil parameters) that have potential as indicators (e.g., bulk density, aggregate stability, and 15-bar water retention). SCS soil sampling protocols are provided in Appendix 8.

3.4 Additional Sampling

Besides the samples collected in the two sampling plans, 20 rangeland sites will be identified for research samples to further evaluate the nematode indicator. These sites will be identified from land use data obtained during the JES. If collected, samples for this effort will be collected following the procedures identified in Section 3.3.2.1 for the collection of soil samples by NASS enumerators.

Section 4
Project Organization

4. 1 Organizational Structure of EMAP

For the organizational structure of central EMAP and its lines of communication with specific resource groups, a good overview is provided in the *Quality Assurance Management Plan* (Kirkland, in prep.). Within the EMAP-Agroecosystem program, Table 4.1 provides a listing of key persons involved in the EMAP-Agroecosystem program and their individual responsibilities.

4.2 Federal Agencies Involved in EMAP-Agroecosystem

The success of the EMAP-Agroecosystem program will depend on the willingness of all involved agencies to participate as full partners in this activity. It is important that the roles and responsibilities be clearly identified to encourage cooperation and successful implementation. In addition to the USEPA, other federal agencies contributing to EMAP-Agroecosystem include the: U. S. Department of Agriculture - Agriculture Research Service (USDA-ARS), U. S. Department of Agriculture - Soil Conservation Service (SCS), and U. S. Department of Agriculture - National Agricultural Statistics Service (NASS).

4.3 Non-federal Agencies Involved in EMAP-Agroecosystem

Many key individuals participate in the various activities of the EMAP-Agroecosystem program. In addition to the federal agencies involved in the EMAP-Agroecosystem, contractors (EG&G, Idaho Falls, Idaho; Lockheed Environmental Systems & Technology Company, Las Vegas, NV; and N&A Nematode Identification Service, Davis, California) and university cooperators (primarily North Carolina State University [NCSU], Raleigh, North Carolina) perform important coordination, support, and analytical roles. The organizational structure for planning, managing, and implementing the Agroecosystem program has evolved gradually and is still being developed.

Table 4.1 Key Personnel and Responsibilities in the Agroecosystem Program.

Technical Director for EMAP-Agroecosystems	C. L. Campbell, USDA-ARS, Raleigh, NC
USEPA Project Officer	S. E. Franson, USEPA, Las Vegas, NV
Laboratory Quality Assurance Manager for EMSL-LV	L. R. Williams, USEPA, Las Vegas, NV
Quality Assurance Coordinator for EMAP	L. Kirkland, USEPA, Washington, DC
Quality Assurance Coordinator for Agroecosystem	B. A. Schumacher, USEPA, Las Vegas, NV
Methods Coordinator for EMAP	G. Collins, USEPA, Cincinnati, OH
NASS Coordinator for EMAP-Agroecosystem	S. Mannheimer, USDA-NASS, Washington, DC
NASS Coordinator for Region VII Pilot Field Program	B. Dobbs, USDA-NASS, Lincoln, NE
SCS Coordinator for EMAP	W. Roth, USDA-SCS, Washington, DC
SCS Coordinator for Region VII Pilot Field Program	N. Helzer, USDA-SCS, Lincoln, NE
National Soil Survey Center Laboratory Coordinator	C. Franks, USDA-SCS, Lincoln, NE
	C. Ditzler, USDA-SCS, Lincoln, NE (1/1/94)
Preparation of Pilot Plan	C. L. Campbell, USDA-ARS, Raleigh, NC
Preparation of Field Operations Manual and Video Tape	M. J. Munster, NCSU, Raleigh, NC D. Neher, NCSU, Raleigh, NC
Preparation of EMAP QA Management Plan	L. Kirkland, USEPA, Washington, DC
Preparation of EMAP-Agroecosystem QA Project Plan	B. A. Schumacher, USEPA, Las Vegas, NV
Field Sampling Training in Lincoln, NE	D. Neher, NCSU, Raleigh, NC M. J. Munster, NCSU, Raleigh, NC B. A. Schumacher, USEPA, Las Vegas, NV
Indicator Leads:	
Biodiversity	G. Hess, NCSU, Raleigh, NC
Crop Productivity	G. Dhakhwa, NCSU, Raleigh, NC M. Munster, NCSU, Raleigh, NC
Insect Biodiversity	S. Peck, NCSU, Raleigh, NC
Land Use and Land Cover	G. Hess, NCSU, Raleigh, NC
Soil Biotic Diversity	D. Neher, NCSU, Raleigh, NC
Soil Quality	G. Olsen, EG&G, Idaho Falls, ID B. McQuaid, USDA-SCS, Raleigh, NC (11/1/93)
Design and Statistics	J. Rawlings, NCSU, Raleigh, NC K. Nauman, NCSU, Raleigh, NC J. Bay, NCSU, Raleigh, NC C. Barrows, NCSU, Raleigh, NC K. Sidik, NCSU, Raleigh, NC L. Stefanski, NCSU, Raleigh, NC
Logistics	M. J. Munster, NCSU, Raleigh, NC
Information Management	M. Tooley, NCSU, Raleigh, NC D. Fiscus, NCSU, Raleigh, NC
Assessment and Reporting	A. Hellkamp, NCSU, Raleigh, NC
Technical Support	C. Harper, NCSU, Raleigh, NC J. Jenco, NCSU, Raleigh, NC

4.4 Cross Terrestrial Coordination

The selection of analytical methods (see section 6.8) for parameters that are common (e.g., soil bulk density) between EMAP-Agro and the other two terrestrial Resource Groups will be performed to enhance comparability of the generated data among the Resource Groups. Where methodological differences are identified, research will be initiated to resolve the differences. Separate QAPPs will be prepared for these additional research projects.

The need for a coordinated, comparable quality assurance program (i.e., the use of the same type of samples, for the same purpose, with the same frequency, and the same acceptance criteria) is a goal that needs to be realized. Current plans in the EMAP-Agro program, although not directly a part of the Region VII Pilot Field Program, include holding a workshop/conference with the soils indicator leads, technical directors, and the quality assurance officers of the three terrestrial Resource Groups. The goals of the workshop will be to: (1) establish common, required (indicators that need to be run by all three groups) indicators, (2) define similar QA/QC sample requirements, (3) agree upon comparable sampling and analytical methods where the same parameter is analyzed by more than one Resource Group, (4) discuss the success/failure of currently established indicators, and (51 to better define the data quality objectives that define if a change in the ecosystem has occurred (i.e., what level of change in a given parameter or suite of parameters is required to clearly show changing ecosystem health).

4.5 Quality Assurance Personnel and Responsibilities

Several personnel are in key positions in the structure of the GA staff. In addition, the indicator leads play an important role in planning and implementing quality assurance for their respective indicators. Quality assurance personnel are included in Table 4.1 and their responsibilities are further delineated below.

4.5.1 Quality Assurance Coordinator for EMAP

The quality assurance coordinator (QAC) has responsibility for the EMAP QA program and its implementation. The QAC serves as an advisor and interacts with the QA representatives for each resource group (e.g., QA Coordinator for Arid Ecosystems) to ensure that each resource group works in a manner consistent with the overall objectives of the QMP (Kirkland, in prep.). The QAC also oversees the development of data quality objectives (DQOs) and documentation standards. For specific duties of the QAC, see Kirkland (in prep.).

4.5.2 Methods Coordinator for EMAP

A methods coordinator has been appointed to oversee methods development and documentation activities for EMAP. The purpose of this position is to coordinate methods development by working closely with the resource group QACs and Indicator Development Coordinators. The main concerns are standardization of standard operating procedures (SOPs) for measurement units, format, QA, and style. Cross-cutting activities among resource groups are a very important aspect of EMAP coordination for the methods coordinator.

4.5.3 USEPA Laboratory Quality Assurance Manager

The USEPA laboratory QA manager (QAM) is responsible for ensuring that each project within an USEPA laboratory satisfies the laboratory*s requirements for QA programs. The laboratory QAM evaluates QA plans, assists in the coordination of systems audits, and disseminates QA information. The QAM at EMSL-LV will work with the EMAP-Agroecosystem QAC to ensure that an appropriate QA program is developed. The EMSL-LV QAM must approve this EMAP-Agroecosystem QAPP.

4.5.4 USEPA Project Officer

The USEPA Project Officer (PO) approves the tasks to be performed by ARG. The PO acts as a controlling mechanism on behalf of USEPA on guidelines, document control (e.g., field pilot plans and QAPPs) meeting deliverable deadlines, audits, and budgetary issues. The PO works closely with the

ARG in coordinating specific aspects of the Agroecosystem program under EMSL-LV control to ensure the success of the program.

4.5.5 Technical Director for Agroecosystems

The Technical Director (TD) for Agroecosystems coordinates many oversight activities, including direct interaction with the ARG participants. Quality assurance functions that the TD performs include:

- o Provide adequate resources,
- o Coordinate development of DQOs,
- o Oversee development of QAPPs,
- o Implement total quality management,
- o Ensure adequate training of personnel,
- o Ensure that audits are conducted, and
- o Support the QA program.

4.5.6 Quality Assurance Coordinator for Agroecosystems

The EMAP-Agroecosystem QAC has overall managerial responsibility for QA in all EMAP Agroecosystem activities, and reports directly to the TD for EMAP-Agroecosystems. The Agroecosystem QAC serves as the QA advisor to the TD and assists the TD in administering the Agroecosystem QA programs. The Agroecosystem QAC is responsible for assisting in the interpretation of USEPA QA policy and developing the QA policies within EMAP-Agroecosystem. The Agroecosystem QAC assures that these policies adequately reflect organizational needs, and that they are consistent with and express the intent of the EMAP QMP and USEPA*s mandatory QA Program. The Agroecosystem QAC is located at EMSL-LV.

The EMAP-Agroecosystem QAC has the following specific responsibilities:

- 0 Providing input to the development of the QMP for EMAP,
- 0 Developing the QAPP for the Agroecosystem Region VII Field Pilot Program,
- 0 Advising the TD, EMSL-LV QAM, USEPA management, and EMAP QAC of any issues which could affect the quality of the study or data,

- Assisting in development of the Agroecosystem information management system for data tracking, generation, and processing activities (entry/verification systems),
- Facilitating DQO development and methods selection within EMAP-Agroecosystem,
- Performing audits for field and laboratory operations both technical systems audits and performance audits,
- Assisting in field training of samplers,
- Developing performance evaluation materials,
- Developing guidance documents,
- Assisting the TD in implementing the QAPP, and other USEPA Quality Assurance Management Staff documents and guidelines for USEPA*s mandatory CIA program,
- Drafting the QA Annual Report and Work Plan summarizing the accomplishments of Agroecosystems and recommending improvements,
- Providing the communication link between the QAC and TD, other Resource Group QACs, and the EMAP QAC,
- Reviewing all contractual QA supporting documentation, and
- Serving as a representative of Agroecosystem during resource group CIA meetings.

Most of these responsibilities are accomplished by review activities and by working closely with the indicator leads and other Agroecosystem participants on QA issues.

4.5.7 NASS Coordinator for EMAP-Agroecosystem and Region VII Field Pilot Program

The USDA-NASS Coordinators are responsible for the participation of the NASS enumerators throughout the EMAP-Agroecosystem program. The NASS coordinator in Washington, DC, is responsible for maintaining continuity of NASS*s participation and role in the EMAP-Agroecosystem program, coordinating field sampling and training, assisting in the development of EMAP-required questionnaires to obtain required crop productivity and land use data, assisting in problem resolution between the NASS and ARG, and administering budgetary issues. The regional NASS coordinators are responsible for assisting in auditing of field sampling operations, coordinating field training and sampling activities, collecting field data forms, reviewing field data, assisting in sampling problem resolution (should any be encountered), maintaining the quality of verbally collected data (in particular, the completeness of the dataset and secondary confirmation of received data by call-backs to farmers),

entering verbally collected data into the NASS database, and acting as the liaison between the NASS enumerators and the ARG.

4.5.8 SCS Coordinator for EMAP-Agroecosystem and Region VII Field Pilot Program

The USDA-SCS Coordinators are responsible for the participation of the SCS soil samplers, the soil preparation and analytical laboratory in Lincoln, Nebraska, and the analysis of all soil parameters, except for the nematode identification and enumeration.

The SCS coordinator in Washington, DC, is responsible for maintaining the continuity/role of the SCS in the EMAP-Agroecosystem program, coordinating field sampling and analytical efforts, training of field personnel, assisting in problem resolution between the SCS and ARG, and administering budgetary issues. The regional SCS coordinators are responsible for assisting in auditing of field and laboratory operations, coordinating field sampling activities, assisting in field sampling problem resolution (should any occur), checking the completeness and appropriateness of the collected site and soil description data, and acting as the liaison between the SCS soil scientists and the ARG.

The National Soil Survey Center Laboratory Coordinator is responsible for ensuring that the collected soil samples are handled, stored, prepared, and analyzed according to EMAP-Agroecosystem required methodologies*and for ensuring that the laboratory is following the EMAP-Agroecosystem QA program. Additional responsibilities of the National Soil Survey Center Laboratory Coordinator include: assisting in technical systems and performance audits, incorporating "blind" performance evaluation materials into soil sample batches, scheduling of sample analysis, and meeting EMAP-required deadlines for delivery of routine and QA/quality control (QC) analytical data.

4.5.9 Indicator Leads

Currently, all but one of the indicator lead positions are held by employees of North Carolina State University, Raleigh, North Carolina. The remaining indicator lead, for the soil quality indicator, is a contractor employee of EG&G, Idaho Falls, Idaho. [NOTE: the indicator lead for the soil quality indicator will be filled by an federal employee of the USDA-SCS beginning on November 1, 1993.] Each indicator lead within the Agroecosystem group has a QA responsibility for the quality of the data

for each of the within-indicator measurements. In order to ensure that the resulting data are of acceptable quality, the indicator lead must be intimately familiar with the components of the indicator, such as sampling protocols, sample preparation, sample analysis, and logistics. The indicator leads are responsible for such activities as assisting the EMAP-Agroecosystem QAC in auditing field and laboratory operations, field training of samplers, performance evaluation, and the development of methods of data verification and validation (which includes accuracy and precision checks). The Agroecosystem QAC serves as an advisor and resource person to the federal, cooperator, and contractor indicator leads. It is anticipated that a cooperative relationship between each indicator lead and the Agroecosystem QAC will develop and be maintained on a continual basis.

4.6 Communications

The establishment of mechanisms and protocols for the exchange of information is essential to the success of any scientific endeavor. This is especially the case for a program of large scope and complexity, such as EMAP. The address of the EMAP-Agroecosystem Resource Group is:

EMAP-Agroecosystem
U.S. Department of Agriculture-Agriculture Research Service
1509 Varsity Drive
Raleigh, NC 27606
Telephone: (919) 5 15-33 11

Periodic communications, including telephone, electronic computerized mail system, surface mail, facsimile mail, and overnight express mail, are maintained among EMAP-Agroecosystem personnel.

Section 5
Quality Assurance Objectives

The QA program for EMAP-Agroecosystem is based on a philosophy of guidance and assistance. There must be a commitment by all personnel to the philosophy of total quality management. Quality assurance is not the responsibility of any one person in the program. Rather, the responsibility is distributed among all personnel, each of whom has a specific role. Those roles must be clearly defined and organized to ensure that an adequate level of quality is attained.

5.7 EMAP-Agroecosystem Quality Assurance Program Objectives

The objective of the EMAP-Agroecosystem QA program is to ensure that the data and statistical products collected by the EMAP-Agroecosystem resource group are of known, documented, and adequate quality to meet and satisfy the needs of the data users. For the Region VII Pilot Field Program, this mission includes establishing and refining criteria to control and assess the quality of data collected in the field and laboratory. Additionally, the QA program for the Region VII Pilot Field Program will test and evaluate the QA procedures implemented in the pilot for application to future EMAP-Agroecosystem studies. These objectives can be accomplished using various approaches and actions as follows:

- **Ensure that all field evaluation and sampling techniques, analytical methods, and data management procedures are documented and distributed to the appropriate participants prior to commencement of the field season,**

- **Conduct training workshops on field procedures for all participants prior to the field season,**

- **Use laboratory assessment samples and procedures to verify and assure the quality of the data,**

- **Conduct various technical systems audits during the field season and laboratory operations,**

- Establish adequate verification and validation techniques for all data, and

- Evaluate the QA data using established statistical methods and document data quality in reports to management.

5.2 Data Quality Objectives

It is a policy of the USEPA and its laboratories that DQOs be developed for all environmental data collection activities. DQOs are statements that describe the level of uncertainty (both qualitative and quantitative) that can be associated with environmental data without compromising their intended use. DQOs thus provide the criteria to design a sampling program within cost and resource constraints or technology limitations imposed upon a project or study.

EMAP is committed to the use of DQOs as a means of assuring acceptable levels of data quality. DQOs will eventually be defined for the different levels of EMAP data collection activities (e.g., program level, project level, indicator level, measurement level) as defined by Kirkland (in prep.). Overall DQOs for the EMAP program have been set to show a 20% change in a response indicator over a decade (2% change per year for 10 years with alpha of 0.2 and beta of 0.3) on a regional scale.

The ARG is attempting to plan and implement sampling and data collection activities to develop the overall EMAP-Agroecosystem DQOs. These objectives will provide information regarding the level of uncertainty that can be associated with EMAP-Agroecosystem data based on its eventual intended use (i.e., providing estimates of status and trends in the ecological condition of agroecosystem resources).

The EMAP-Agroecosystem resource group has not yet collected enough information to establish DQOs. Accordingly, one of the primary purposes of the 1993 Pilot Field Program is to obtain sufficient, quality data that can be used in the establishment of the DQOs. The data collected during the 1993 Pilot Field Program will be used to establish a baseline from which comparisons of future ecological trends and the assessment of type I and II error rates (false positive and false negative errors, respectively) can be made. After sufficient data has been

collected to establish the DQOs, assessments can be performed to determine the allowable rates of type I and II errors. The goal for the allowable rates of these errors are 20 and 30% for type I and II errors, respectively, with the power of 0.7.

The CIA concern for the 1993 Pilot Field Program is to control, assess, and minimize the component of variance that is due to measurement error. Therefore, the focus for the Region VII Pilot Field Program will be on measurement quality objectives (MQOs).

Based on the currently perceived data quality requirements for each indicator, acceptance criteria for measurement data are defined for several attributes of data quality and described in the following sections. These criteria are established based on consideration of important sources of error, where known. For each ecological indicator being used for the Region VII Pilot Field Program, DA objectives are defined to control and evaluate measurement error attributable to the collection and analysis of samples or data. As data become available to evaluate error at levels above the measurement level (e.g., indicator level), additional DA objectives will be defined.

5.3 Attributes of Data Quality

For each indicator, CM objectives (associated primarily with measurement error) have been established for several different attributes of data quality. Specific objectives for the crop productivity, land use and land cover, pest management, soil quality, soil biotic diversity indicators are presented in sections 6.5, 6.6, 6.7, 6.8, and 6.9, respectively. The following sections define the data quality attributes and present approaches for evaluating them against acceptance criteria established for the program.

5.3.1 Precision, Bias, and Accuracy

Precision and bias are estimates of random and systematic error in a measurement process (Hunt and Wilson, 1986). Collectively, precision and bias provide an estimate of the total error, or uncertainty, associated with an individual measurement or set of measurements. Systematic errors are minimized by using validated methodologies and standardized procedures. Precision is the level

of agreement among multiple measurements of the same characteristic. Accuracy is the difference between an observed value and the "true" or theoretical value. Bias is a systematic error inherent in a method or caused by some artifact or idiosyncrasy of the measurement system (Taylor, 1987).

Precision in absolute terms is estimated as the sample standard deviation when the number of measurements is greater than two:

$$s = \sqrt{\frac{\sum (X_i - \bar{X})^2}{(n - 1)}}$$

where X_i is an individual measurement, and $\bar{X}$ is the mean of the set of measurements. Relative precision for such measurements is estimated as the relative standard deviation (RSD or coefficient of variation, [CV]):

$$RSD = s / \bar{x} \times 100$$

where s is the sample standard deviation of the set of measurements and $\bar{x}$ equals the mean value for the set of measurements.

Precision based on duplicate measurements is estimated based on the range of measured values (which equals the difference between the two measurements). The relative percent difference (RPD) is calculated as:

$$RPD = |x_1 - x_2| / \bar{x} \times 100$$

where x_1 is the first measured value, x_2 is the second measured value, and $\bar{x}$ is the mean value of the two sample measurements.

For repeated measurements of the same characteristic, net bias (B) is estimated in absolute terms as:

$$B = \bar{x} - TV$$

where $\bar{x}$ equals the mean value for the set of measurements and TV equals the theoretical or target value. Bias in relative terms ($B\%$) is calculated as:

$$B\ (\%) = \frac{\bar{x} - TV}{TV} \times 100$$

where $\bar{x}$ equals the mean value for the set of measurements and TV equals the theoretical or target value.

53.2 Completeness

Completeness is the quantity of valid data collected with respect to the amount intended in the experimental design. Within each indicator, completeness objectives have been established and are presented in section 6 based on the percentage of valid data obtained versus the amount of data expected.

5.3.3 Comparability

Comparability is defined as the confidence with which one data set can be compared to another (Stanley and Verner, 1985; Smith et al., 1988). For all indicators, comparability is addressed by the use of standardized sampling and measurement procedures and analytical methodologies by all sampling crews and analytical laboratories. Comparability of data within and among indicators is also facilitated by the implementation of standardized QA/QC techniques and standardized acceptance criteria. Comparability is also addressed by providing results of CA sample data, such as estimates of precision and bias, conducting methods comparison studies when necessary, and conducting interlaboratory performance evaluation studies. These latter activities allow for comparability to be addressed through time or by external data users.

5.3.4 Representativeness

Representativeness is defined as "the degree to which the data accurately and precisely represent a characteristic of a population parameter, variation of a property, a process characteristic, or an operational condition" (Stanley and Verner, 1985). At one level, representativeness is affected by problems in any or all of the other attributes of data quality. Use of

QA/QC samples which are similar in composition to samples being measured provides estimates of precision and accuracy that are representative of sample measurements.

At another level, representativeness is affected by the selection of sites to be sampled and measured, and the time period when data are collected. Representativeness of site selection has been addressed through an *a priori* selection of sites following standardized EMAP and NASS selection protocols throughout the state of Nebraska. Further, the positioning of the sample transects within a selected field will be performed using a random number-generated transect midpoint. A more detailed description of these site selection protocols has been provided in Section 3 of this QAPP.

It is the goal of the EMAP-Agroecosystem program to collect all samples during the post harvest and pre-frost time frame. It is generally believed that this would be the best time to sample to avoid any introduced variability in soil properties due to anthropogenic inputs (e.g., fertilizers and pesticides) and to avoid the potential killing effects of frost on nematode communities.

Section 6
Quality Assurance Procedures

The following sections address CA components that directly affect the quality of the data collected for the EMAP-Agroecosystem indicators. Ten critical components of the Agroecosystem QA program for the 1993 Region VII Pilot Field Program are:

- **Assist and monitor NASS survey data collection,**
- **Conduct a training course prior to initiation of field activities,**
- **Use experienced indicator leads as trainers,**
- **Develop CIA program and establish measurement quality objectives for all variables for all indicators,**
- **Develop detailed field protocols for crew sampling and measurements,**
- **Conduct a technical, systems audit (TSA) during the field season,**
- **Collect and develop soil-based performance evaluation materials for the assessment of bias and long-term precision of the analytical laboratory,**
- **Coordinate a DA program with 'the SCS National Soils Analytical Laboratory including sample tracking, sample preparation, sample batching with blind samples, and quality control criteria,**
- **Evaluate field and laboratory DA/W data during the study for real-time CA where appropriate and feasible, and**
- **Interface closely with information management and logistics personnel to ensure smooth coordination and communication among these important aspects of field activities.**

The following sections (6.1 through 6.4) address QA components that apply to all of the indicators for the 1993 Region VII Pilot Field Program. The subsequent sections (6.5 through 6.9) will address QA procedures related to specific indicators.

6.1 NASS Survey Data Collection

The EMAP-Agroecosystem QA program will take advantage of QA procedures already employed by NASS during the collection of verbal survey data for the Fall Sampling Survey. NASS views QC as the process of eliminating as many survey errors as possible. To limit errors, every survey process must be associated with some type of GA/QC procedure. The major survey processes in the Agroecosystem 1993 Pilot Field Program amenable to QC considerations include: (1) area sampling frames - their construction, maintenance, and sampling; (2) survey specifications and questionnaire design; (3) training (to be discussed in Section 6.2); (4) survey data collection; and (5) data processing, editing, and review.

6.1. 1 Area Frame Development

General procedures for selection of pilot segments according to either the NASS rotational panel or EMAP hexagon scheme are presented in Section 3. Prior to drawing segments, however, the area frame must be constructed. This activity is handled by NASS and will be performed following standardized NASS protocols and QA procedures. Some of the quality assurance methods in frame development are documented in *Area Frame Design for Agricultural Surveys* (Cotter and Nealon, 1987). These procedures are important for ensuring that no land area is counted twice or unintentionally omitted and that strata are correctly identified. The ARG is responsible for verifying that the PSUs identified during the area frame development contain the appropriate EMAP hexagon centroid.

6.1.2 Survey Specifications and Questionnaire Design

Verbal survey data for the EMAP-Agroecosystems program will come from the Fall Survey (a part of the 1993 Pilot Field Program) administered by NASS. The Fall Survey is a set of questions especially developed for the EMAP-Agroecosystems program. Additional information needed by the EMAP-Agroecosystems program, mainly in the areas of post-harvest concerns such as crop yields and management practices, will be asked of the farmers interviewed by the NASS enumerators. The ARG and NASS will work together to ensure that all the appropriate questions required for both

organizations are incorporated into the questionnaire to be used by the NASS enumerators and that the questions are in a proper format to obtain the required data.

6.1.3 Survey Data Collection

NASS has an established QA program that will be used during the collection of the verbal survey data for the Fall Survey used by the EMAP-Agroecosystem program. Copies of the appropriate QA documents and survey evaluation reports will be obtained from NASS and maintained by the EMAP-Agroecosystems QAC and ARG during 1993. A brief description of the NASS CA program is provided in the following paragraphs.

Once field interviews begin, the supervisory enumerators are responsible for assuring that data are taken correctly. The supervisors accompany new enumerators on their first day of interviewing and meet with experienced enumerators after the first few interviews of each survey. If there are any problems, the supervisor either instructs the enumerator individually or holds a re-training meeting, if warranted.

For the 1993 Pilot Field Program Fall survey, approximately two interviews from each enumerator*s workload will be checked by telephone follow-up or site visit. Questions from a worksheet will be asked. to verify that the interviewer did contact the farmer, that a particular crop was grown, etc. The responsibilities of supervisory enumerators are given in the *NASDA Supervisory Enumerator Handbook* (USDA-NASS, 1990).

Another aspect of the NASS QA program is the measurement of crop ‘objective yields. The determination of objective yields is performed by specially trained NASS personnel. These trained surveyors will visit a given field during the growing/harvest season and quantify the yields of the crop. The primary purpose for this determination is for comparison with the farmer*s verbally reported yield values.

6.1.4 Data Processing, Editing, and Review

Survey data are subject to a three-stage processing, editing, and review program. first, the supervisory NASS enumerator checks the data for reasonableness and completeness. If deficiencies are identified, the supervisor will return the questionnaire back to the enumerator for resolution of the identified problems.

Once the revised and completed questionnaires are received by NASS, the questionnaires are reviewed and edited by a statistician. The statistician reviews the forms for extraneous values or apparently erroneous values. Again, if unsatisfactory data are identified, they are returned to the supervisory enumerator who is responsible for correcting identified problem areas or returning the questionnaires to the field enumerators for further corm&on. Where possible, telephonic communications will be used to clarify ambiguities or resolve conflicts promptly with the data generators.

After these two manual edits, data are entered into the computer where another detailed edit is performed. Data entry is performed using a double-entry system in which two data managers will independently enter the same Dataset. The computer then performs a comparison between the two entered datasets and provides a printout indicating where differences exist. When differences are identified, the two data managers are then responsible for their resolution and correction of the inaccurately entered data. Further, a computer program will be run to verify that responses are appropriate to questions, to check for internal consistency, and to determine if the data are within the expected ranges for USEPA Region VII and the state of Nebraska. Problems discovered at this level are brought to the attention of the statistician for resolution.

6.2 Field Training

A crucial element of QC is sufficient training of the field staff. The Fall Survey, which will start in November (post-harvest sampling), will consist of the collection of both verbal survey data and soil samples by NASS enumerators. These two activities generally run concurrently with each other or with the questions (and permission to sample soil) being asked one day, followed by soil

sampling on the next day. NASS, the ARG, and EMAP-Agroecosystems QAC will cooperate in planning and running the training session for these activities. The training session of the 1993 Pilot Field Program will be conducted on October 13 and 14, 1993, in Lincoln, NE.

In the training program, the enumerators will review the questionnaire for clarity and completeness, learn how to collect the soil samples by hands-on training in the field, and be provided with all the appropriate handbooks, forms, and equipment necessary to start the Fall Survey sampling program. Training will be provided primarily by the experienced indicator leads, NASS supervisors, and the EMAP-Agroecosystem QAC.

During the 1993 Pilot Field Program, USDA-SCS soil scientists will also be collecting soil samples for routine and "special" soil parameters. The SCS will be responsible for the training of the SCS soil samplers prior to any field sampling of soils for the EMAP-Agroecosystems program since soil sampling is one of the primary responsibilities of the SCS personnel. Qualified soil scientists will be sent to the field by the SCS who are capable of collecting the necessary soil samples, characterizing/describing the soil (from the pit), and who have sufficient field experience in determining the major (or dominant) soil series of the map unit in which the sampling site is located. The selection of the soil scientists to perform these functions will be at the discretion of the SCS.

6.3 Standard Operating Procedures

The use of written standard operating procedures (SOPs) for sampling and analysis helps to ensure consistency in planning, implementation, and analytical activities over time and among personnel for routine activities. Detailed procedures for the collection of verbal data and soil samples by the NASS enumerators are provided in NASS's *Agricultural Surveys: Interviewer's Manual* (USDA-NASS, 1993) and in Appendix A, respectively. Soil sampling and site description SOPs used by the SCS soil samplers are presented in the *Soil Survey Manual* (USDA-SCS, 1951); an abbreviated procedure is presented in Appendix B. Additional information on the sampling requirements and methods of the SCS may be found in the *National Soils Handbook* (USDA-SCS, 1983).

All soil sample preparation and laboratory analytical work, excluding that work performed in conjunction with the soil biotic diversity indicator, will be performed by the USDA-SCS National Soil Survey Laboratory in Lincoln, Nebraska. SOPs are documented in the *Soil Survey Laboratory Methods Manual* (USDA-SCS, 1992). A list of the soil parameters to be analyzed and the standard method to be used for the analyses are presented in section 6.8. All laboratory personnel are trained and proficient in the soil test methods used by MAP-Agroecosystem.

For the soil biotic diversity indicator, nematode separation, identification, and enumeration will be performed by the N&A Nematode Identification Service, Davis, California. Soil samples will be collected following the SOP identified for the NASS enumerators in Section 3.3.2.1, Nematodes will be extracted from the soils using Cobb*s sifting and gravity method (Ayoub, 1980; Thorne, 1961) modified by triplicate passes through 710 *:*m, 250 *:*m, 150 *:*m, 75 *:*m, 45 *:*m, and 38 *:*m mesh sieves. After sieving, the centrifugal-flotation method of Caveness and Jensen (1955) modified by using a 1:1 sugar solution (1:1 v:v) and centrifuging for 1 min will be used. SOPs for the modified Cobb*s sifting and gravity method and the modified sugar centrifugal-flotation method are presented in Appendices C and D, respectively. Classification of trophic groups will follow Yeates et al., (1993) and taxonomic classification of nematode families will follow Maggenti (1982, 1991).

6.4 The Audit Program

A TSA is an on-site visit used to verify conformance to the QAPP and to established SOPs in the generation of the environmental data. The audit determines whether all data collection participants are adhering to protocols in a consistent manner. Audi also help determine whether the QAPP and SOPs are adequate for the objectives of the project. These audits are documented in reports to management. The Agroecosystem QAC, in conjunction with the indicator leads, supervisory NASS personnel, and supervisory SCS personnel, are responsible for developing, conducting, and reporting the results of the audits. It is recommended that the indicator leads participate in the conducting of the audits since they should be the individuals most familiar with the sampling and analytical methods.

To determine whether the EMAP-Agroecosystems sampling protocols are being followed properly by the NASS enumerators, at least two field systems audits will be performed by the *EMAP-Agroecosystems QAC, NASS, and/or members of the ARG. Field system audits will be performed on at least two different field sampling crews. Additional audits may be scheduled if time permits or serious deficiencies are identified. The results will be reported to the EMAP-Agroecosystem TD, EMAP QAC, EMAP-Agroecosystem QAC, EMAP-Agroecosystem Project Officer, and appropriate indicator leads.

To ensure that the EMAP-Agroecosystems sampling protocols are being followed properly by the SCS soil scientists, at least one field systems audit will be performed by the EMAP-Agroecosystems QAC, SCS, and/or members of the ARG. Additional audits may be scheduled if time permits or serious deficiencies are identified. The results will be reported to the EMAP-Agroecosystem TD, EMAP QAC, EMAP-Agroecosystem QAC, and the appropriate indicator leads.

The SCS analytical laboratory and the N&A Nematode Identification Service, Davis, California, will be audited at least once during the sample analysis phase of the project. The technical system audit will take place sometime during the preparation and analysis of the first third of the soil samples.

Corrective actions that will be taken if the audits reveal problems include additional staff training and reviewing and improving the SOPs. Determining and taking the appropriate action will be the responsibility of the Indicator Lead in consultation with the EMAP-Agroecosystem TD and the QAC. The QAC is responsible for tracking problems or discrepancies, the corrective actions taken, and the remedial effects. If necessary, a follow-up audit will be performed to verify that the problem has been remedied.

6.5 Crop Productivity Indicator

When people are concerned about agriculture, crop production is often the focus. Crop productivity indicators are being developed to address the broader value “productivity”, but they will also give an indication of the quality of air, water, and soil. The ARG is focusing on field-level

at least as much food and fiber as it is currently producing. The *status quo* is the reference point because of a lack of definition of "adequate" production or "sufficient" production efficiency. To identify these efficiencies would involve broad ecological issues of land allocation, human population and diet, which go beyond the scope of EMAP. Field-level sustainability is inherently a trend-based issue and cannot be assessed in a one-year pilot. Still, it is important to attempt the calculations and to look at spatial variability and differences among crop species. It should be noted that certain soil properties or management practices may give advance warning about whether productivity can be sustained, but these are not crop productivity indicators, *per se.*

Crop productivity indicators are being developed to evaluate the condition of crop plants from two perspectives, represented by the following assessment questions:

- Is the land meeting its productive capacity (defined by soil, climate, and past performance), and

- Is production efficiency rising of falling over time?

A more complete description of the crop productivity indicator is presented in section 5.1 of the *Agroecosystem Pilot field Program Plan* (Campbell et al., in prep.).

6.5.7 Crop Productivity Measurements

The majority of data for the crop productivity indicator are collected by the NASS enumerators during their verbal Fall Survey for the EMAP-Agroecosystem program. Queries are made of the farmer concerning the crop (e.g., type, acreage planted, yields obtained, planting rates, row spacing, and planting schedule) and about the management inputs (e.g., fertilizer usage type, amount, nutrient content, timing of application; pesticide usage - type, amount, timing, purpose; irrigation practices - water source, quantity used, application method; tillage practices; and crop rotation scheme). A complete copy of the NASS survey questionnaires can be found in the *Agroecosystem Pilot Field Program Plan* (Campbell et al., in prep.).

Additional supplementary data will be collected for the crop productivity indicator from varied sources. Supplementary data include: weather data (e.g., precipitation, temperature ranges, solar radiation, relative humidity, and wind speed); miscellaneous production practices (if not queried during the NASS Fall Survey); reference yield values (for the purpose of calculating the normalized yield); and the soil map unit. Sources for these .data are: the High Plains Climate Center and NASS for the weather data; the literature, USDA-ARS, and NASS for the miscellaneous production practices (e.g., standard crop moisture contents, depth of seed planting, and planting density); NASS for the reference yields; and the USDA-SCS for the soil map units.

Examples of the field measurements necessary and ancillary data for the five proposed indices are presented in Table 6.1.

All of the field measurements in Table 6.1 could be considered critical to program objectives, with the exception that useful indices can and will be calculated that ignore manure contributions to nitrogen. In addition to the above, standard moisture contents will be identified so that the first step can be taken toward combining efficiency indices across grain crops.

6.5.2 Quality Assurance Measurements for Crop Productivity Indicator

The quality assurance measurements for the crop productivity indicator are the responsibility of NASS since nearly all the data are collected by the NASS enumerators. A description of the NASS QA program associated with survey data collection has been presented in Sections 6.1.3 and 6.1.4. In brief, the NASS QA program consists of secondary confirmation of verbal data by telephone follow-up calls or site visits, statistician review for extraneous and erroneous data, double-entry system for computer input, objective yield determinations, and internal consistency checks against regional databases.

6.5.3 Information Management, Data Verification, and Validation

Verbal survey data are subject to a three-stage processing, editing, and review (verification and validation) program by NASS. A brief description of this process has been provided in Section 6.1.4. Ultimately, all collected survey data will be put into electronic form by NASS. Once the

dataset has been entered, a few calculations will be performed by NASS. For example, the information on fertilizer applications is used to derive the loadings of N, P, and K (as N, P_2O_5 and K_2O) to the agricultural system.

Table 6.1 Measurements to be used in the development of the crop productivity indicator.

Index or group of indices	Field (questionnaire) measurements	Ancillary data [source]
nitrogen use efficiency	crop, field size[1], yield, unit weight, applications of manures and commercial fertilizers (composition, rate, area treated)	nitrogen contents of various types of manure [published]
irrigation water use efficiency	crop, field size[1], yield, unit weight, area irrigated and amount of irrigation water applied.	none identified
standardized yield: observed vs. long-term mean	crop, yield, unit weight	NASS county average yields by crop for a 10-12 year period prior to sample year
adjusted yield: observed vs. expected	crop, yield, unit weight	soil map units on sample fields [matching aerial photos with soil survey maps], expected yields for various crops (by map unit, by county or other soil survey region) [State Soil Survey Database], standard unit weights for various crops [published]
adjusted yield: using models (corn, soybean, wheat only)	crop, area planted, seeding rate, row spacing, yield, and unit weight, plus detailed information on management practices and when they were performed, plus variety name for soybeans	soil map units on sample fields [see above], weather data for the current crop year [to be determined], other parameters incl. genetic coefficients for different crops [literature, modelers]

[1]Area planted and area harvested may also be used, in addition to field size (cropland acres).

NASS procedures for editing may be found in the NASS *Supervising and Editing (S&E) manual* (USDA-NASS, 1991). An S&E manual will be written by NASS for the 1993 Agroecosystem Pilot Field Program.

The fall questionnaire data are not subjected to systematic validation by the ARG at this time. Occasional checks for reasonableness and consistency are run if an ARG member identifies a possible problem.

For ancillary data, no data verification/validation procedures are planned.

Most of the calculations that lead up to the eventual indices are done by the indicator lead, statistician, and crop modeler associated with the crop productivity indicator. The only QA procedures planned for these efforts are: 1) to do some of the index calculations by hand, as a check against the computer programs, 2) to perform sensitivity analyses on the models, and 3) to carefully document the procedures used to arrive at the indices.

6.5.4 Measurement Quality Objectives for Crop Productivity

The ARG has not set measurement quality objectives (MQOs) for questionnaire data, excluding completeness. A completeness level of 90% is required for the EMAP-Agroecosystem program. No MQOs have been established for ancillary data.

6.6 Land Use and Land Cover Indicator

A concept central to the field of landscape ecology is that the spatial structure of a landscape affects the flow of energy and materials, and the movement of organisms among its components. The influence of a landscape*s spatial structure is apparent at many scales. There are interactions within an agroecosystem, such as those between a hedgerow and an adjacent field; and the cumulative effects of agroecosystems in a landscape on, for example, water quality and the habitat of far-ranging species. Landscapes are also characterized by temporal patchiness on many scales.

There are annual changes in agricultural land use, as well as decades-long processes, such as land cycling between agriculture and other uses.

Changes in land use patterns may foreshadow ecological change. For example:

- a change in acreage planted to chemical-intensive crops might affect water quality in surrounding areas,
- removal of hedgerows, windbreaks, and shelter belts may lead to increased soil erosion,
- bringing marginal farmland into production may lead to reduced productivity and increased erosion, and
- changes in the amount and spatial structure of non-cropped land areas in the landscape may affect populations of plants and animals that utilize those areas.

Land use changes may also reflect changing ecological conditions. For example:

- global climatic changes may bring about major shifts in cropping regions or cropping patterns within regions, and
- degradation of soil or water quality may lead to the abandonment of cropped land.

Two closely related indicators address these issues:

- *Land* use and cover: an accounting of the amount of land in various land use and cover categories. The remainder of this section focuses on this indicator.
- *Landscape* structure: an analysis of the spatial structure of the various components of landscapes. This research effort was part of the 1992 pilot in North Carolina and analyses will be continued as part of that pilot. No new work in this area is planned for the 1993 pilot in Region VII - Nebraska.

6.6.1 Land Use and Land Cover Measurements

All the data for the land use and land cover indicator are obtained during the NASS area frame development process or are collected by the NASS enumerators during their verbal June Enumerative and Fall Surveys for the EMAP-Agroecosystem program. Queries are made of the farmer concerning the land use classification of his/her fields by NASS enumerators. Land use classifications include: cropland (subdivided by crop), permanent pasture (including rangelands), pasture croplands, idle croplands, occupied farmstead or dwelling, farm ponds, and others which include woods, road, ditches, waste, etc. Additionally, queries will be made of the farmer concerning the crops planted (e.g., type, acreage planted, yields obtained, planting rates, row spacing, and planting schedule) and about the management inputs (e.g., fertilizer usage - type, amount, nutrient content, timing of application; pesticide usage - type, amount, timing, purpose; irrigation practices - water source, quantity used, application method; tillage practices; and crop rotation scheme). A complete copy of the NASS survey questionnaires can be found in the 1993 *Agroecosystem Pilot Field Program Plan* (Campbell et al., in prep.).

Once these data have been collected by NASS, the ARG will calculate four indices to assess the changes in the agroecosystem land use and land cover structure. These indices are: (1) agricultural land use intensity, (21 annually harvested herbaceous cropland extent, (31 annually harvested herbaceous cropland diversity, and (4) farm pond extent. The data for the agricultural land use intensity index are derived from the NASS area frame development process (briefly described in sections 3 and 6.1.1) while the data for the remaining three indices are obtained directly from the NASS verbal surveys.

6.6.2 Quality Assurance Measurements for Land Use and Land Cover Indicator

The QA measurements for the land use and land cover indicator are the responsibility of NASS since all the data are collected or derived by NASS. A description of the NASS QA program associated with area frame development and survey data collection has been presented in Sections 6.1.1 and 6.1.3, respectively. Cotter and Nealon (1987) further describe the development and associated QA procedures for the NASS area frame. The NASS GA program for survey collected data consists of secondary confirmation of verbal data by telephone follow-up calls or site visits,

statistician review for extraneous and erroneous data, double-entry system for computer input, objective yield determinations, and internal consistency checks against regional databases.

6.6.3 Information Management, Data Verification, and Validation

Verbal survey data are subject to a three-stage processing, editing, and review (verification and validation) program by NASS. A brief description of thii process has been provided in Section 6.1.4. Ultimately, all collected survey data will be put into electronic form by NASS for utilization by the ARG.

NASS procedures for editing may be found in *the NASS Supervishg end Editing (S&E) manual* (USDA-NASS, 1991). An S&E manual will be written by NASS for the 1993 Agroecosystem Pilot Field Program.

In addition to NASS QA checks, the ARG performs several consistency checks on the JES data with respect to land use indicators:

- for each JES record, check that all of the crops and other land uses in the record sum to the independently obtained field size. No difference is acceptable.

- for each JES record, compare the amount of the resource (e.g., annually harvested herbaceous cropland) obtained by two methods of calculation (subtractive and additive methods) to ensure that all the land has been properly accounted. In the *subtractive method,* all land not in the resource class is subtracted from the total field size. In the *additive method,* all land in the resource class is summed. The results from the two methods should be equal. Any discrepancies will be flagged and examined. No difference is acceptable.

- check that the sum of the expanded segment areas of all the JES records is equal to the area of the state. Acceptable deviation has yet to be defined, but f 1% is the current target being considered.

- as part of the Fall Survey, which is administered to a subset of the segments visited in June, a land use history will be obtained for the past three years. Using the Fall Survey data, a check for discrepancies in land use reported on the Fall and June Enumerative surveys will be performed. The enumerator visiting a segment in the fall should have the information collected about that segment in JES and will be able to explore the causes of any discrepancies.

6.6.4 Measurement Quality Objectives for Land Use and Land Cover

The ARG has not set measurement quality objectives (MQOs) for questionnaire data, excluding completeness. A completeness lever of 90% is required for the EMAP-Agroecosystem program.

During the examination of the NASS data for use in the determination of the land use and land cover indices, several MQOs have‘been established for the accuracy of the recorded NASS survey data. Each of these goals are presented above during the discussion of the additional QA checks for consistency of the NASS collected verbal survey data to be performed by the ARG.

6.7 Pest Management Indicator

In the 1993 Agroecosystem Pilot Field Program, specific pest management information will be collected for the first time as part of the EMAP-Agroecosystem program. Information on the type and amount of each pesticide used on the selected field will be collected from the farmer. The target insect pest will also be identified for each insecticide application.

The pesticide information will be used primarily as an associative variable during this year*s pilot. For example, the soil biotic diversity (Section 6.91, being assessed using indices of nematode community structure, will use pesticide (especially nematicide) information as a covariate in statistical

The IPM concept promotes the use of chemicals only after the pest has caused crop damage above some economic threshold. The use of IPM is thought to be a sustainable agricultural practice. Scouting, crop rotation, the use of beneficial insects, and time of planting are a few of the strategies used to reduce the amount of pesticide that is used on a particular crop. The spatial extent and frequency of implementation of IPM by the grower may be indicative of lower pesticide use and improved condition in agroecosystems. By knowing the pesticide applied to the field, the target pest, and whether IPM practices are being used, an indication of the pest spectrum may also be obtained for the state of Nebraska. Therefore, IPM will be explored as a correlative measure with other condition indicators.

6.7.1 Pest Management Measurements

All the data for the pest management indicator will be collected by the NASS enumerators during their verbal Fall Survey for the EMAP-Agroecosystem program. NASS enumerators will collect data on the type, rate, and frequency of pesticide use; including insecticides, fungicides, nematicides, and herbicides. The crop treated, the number of acres treated, the mode of application and the time of application will also be recorded. NASS enumerators will then inquire about the target pest for each insecticide application. The farmer*s awareness of IPM concepts will be determined both by asking about his/her familiarity with the term and whether typical IPM practices are being used. in pest management decisions. A complete copy of the NASS survey questionnaires can be found in the 1993 *Agroecosystem Pilot Field Program Plan* (Campbell et al., in prep.).

Several data items will not be obtained in the Fall Survey questionnaire. For example, the chemical grouping in terms of persistence, toxicity, mode of action and chemical formulation will be obtained from published sources. The spectrum of plants and pests against which the pesticides are effective, as well as for which crops and pests they are registered in the state of Nebraska will also be important for some planned analyses and will be obtained from the Nebraska Department of Agriculture or Cooperative Extension Service.

6.7.2 Quality Assurance Measurements for Pest Management Indicator .

The GA measurements for the land use and land cover indicator are the responsibility of NASS since all the data are collected by NASS. A description of the NASS QA program associated with survey data collection has been presented in Sections 6.1.3 and 6.1.4. The NASS QA program for survey collected data consists of secondary confirmation of verbal data by telephone follow-up calls or site visits, statistician review for extraneous and erroneous data, double-entry system for computer input, objective yield determinations, and internal consistency checks against regional databases.

6.7.3 Information Management, Data Verification, and Validation

Verbal survey data are subject to a three-stage processing, editing, and review (verification and validation) program by NASS. A brief description of this process has been provided in Section 6.1.4. Ultimately, all collected survey data will be put into electronic form by NASS for utilization by the ARG.

NASS procedures for editing may be found in the NASS *Supervising and Editing (S&E) manual* (USDA-NASS, 1991). An S&E manual will be written by NASS for the 1993 Agroecosystem Pilot Field Program.

Data analysis will involve the classification of pesticides into ecologically meaningful groups such as persistence, toxicity, chemical formulation, mode of action, and spectrum of pests affected. The spatial distribution of pesticide use will be explored using standard statistical methods. Much of the effort for the pesticide information will be focused on exploring correlations and associations between pesticide use and key indicators.

The fall questionnaire data are not subjected to systematic validation by the ARG at this time. Occasional checks for reasonableness and consistency are run if an ARG member identifies a possible problem.

For ancillary data, no data verification/validation procedures are planned.

6.7.4 Measurement Quality Objectives for Pest Management

The ARG has not set measurement quality objectives (MQOs) for questionnaire data, excluding completeness. A completeness level of 80% is required for the EMAP-Agroecosystem program. Pesticide application information is inherently difficult to collect. Growers can be reluctant to disclose this information because of the public*s perception of pesticide problems. Another purpose for including the pesticide questions in the 1993 pilot will, therefore, be to determine our ability to collect this information. No MQOs have been established for ancillary data.

6.8 Soil Quality Indicator

Soils function as sinks and sources of biogeochemical elements, as filters for pollutants; and as an environment for growth of plants and other biological communities. Soils are liable to change, gradually or abruptly and partly irreversibly, due to human use. For example, soil structure is especially sensitive to human activities (Kay, 1989). The main human activities affecting soils in agroecosystems are vehicular traffic, tillage, use of agricultural chemicals, waste disposal, and land use. To protect and conserve agricultural soils from degradative processes, specific practices such as conservation tillage, residue management, crop rotation, careful selection of crops for specific soils, and use of amendments are widely implemented on U.S. cropland. The long-term goal of soil quality monitoring and assessment in agroecosystems is to provide a regional assessment of the cumulative soil response to these conservation efforts.

The following assessment questions will be addressed of soil quality in the 1993 Agroecosystem Pilot Field Program in Region VII:

1) **What proportion of agroecosystem units has erosion exceeding tolerable limits as defined, by the erosion tolerance (T) value and Watershed Erosion Prediction Project?**

2) **What proportion of agroecosystem units has soil alkalinity and salinity values that impact productivity?**

3) What proportion of agroecosystem units has leachable soils and is receiving applications of leachable pesticides?

4) What proportion of agroecosystem units has soil quality sufficient to sustain productivity of crop and noncrop plants?

5) What proportion of agroecosystem units has soils with a physical structure that can not support soil microbes?

Four long-term objectives and one short-term objective have been identified for the soil quality indicator. The long-term objectives are:

1) to determine the *rates of change* of soil quality since standards of soil quality will vary with climate and soil,

2) to combine indicator measurements into quantitative indices so that general statements about soil quality on a regional basis can be made. Several possible indices include: soil structure, soil fertility, contamination, leaching potential, sensitivity to degradation, erosion, and productivity (Table 6.2),

3) to combine with other pilot data into a picture of overall agroecosystem health, and

4) to integrate information on the health of agricultural soils in the U.S. with information on soils in forests and arid ecosystems to provide an overall picture of soil quality across terrestrial ecosystems.

The main short-term objective in the assessment of soil quality is to determine the range and frequency distribution (in proportion of land area) of individual measurements and to evaluate how well the chosen measurements and derived indices will reflect changing conditions.

Table 6.2 Research indices of soil quality.

Assessment or index	Measurements
Contamination/Toxins	Lead/cadmium/mercury/zinc
Anthropogenic	and other trace metal contaminants
Nonanthropogenic	pH
salinization	Exchangeable sodium percentage
alkalinization	Base saturation
	Electrical conductivity or calcium carbonate equivalent
Soil structure	Bulk density[a]
(tilth, porosity)	Available water capacity[a]
	Porosity[a]
	Organic carbon
	Clay content
	Aggregate stability[a]
Soil fertility	Base saturation
	Extractable phosphorus
	Organic matter
	pH
Leaching Potential/	Slope
Adsorption Potential/	Infiltration (Hydrologic group)
Run-off Potential	Horizon depth
(SCS ratings)	Organic carbon
Sensitivity to	Texture
degradation from	Drainage
intensive agriculture	Erosion rate
	Soil depth
	Rooting depth
	Depth to water table
	Restrictive soil layers
	Landscape position (slope position)
	Taxonomic order or suborder
Erosion	'Highly Erodible Land' rating-water
	'Highly Erodible Land' rating-wind
	Erosion index (T)
Productivity	Soil properties such as bulk density, organic carbon, pH, exchangeable cations, cation exchange capacity

a = parameter determined from soil samples collected by the SCS.

6.8.1 Soil Quality Measurements

The initial set of physical and chemical indicators of soil quality to be measured in the 1993 Agroecosystem Pilot Field Program are described briefly in the following sections. These indicators were chosen for evaluation because they are known to be important to the functioning of the soil system, are affected by anthropogenic stresses, and are likely to be measurable in a single sampling period on a regional basis. Many of these indicators are also key variables in soil productivity models.

6.8.1.1 Organic Carbon

Organic matter is considered important for the long-term physical, chemical, and biological functioning of soils; it stabilizes soil structure, increases the cation exchange capacity and water-holding capacity of soils, and supplies nutrients for plants and microorganisms. Loss of organic matter is increased by tillage and affected by management practices such as choice of crops, stubble mulching, fallowing, and use of organic amendments. Organic matter is lost due to soil erosion (often accompanied by a loss in nutrients), deterioration of soil structure, and diminished soil workability (Pierce and Lal, 1991) Frye et al., 1982). Depletion of soil organic matter and erosion are interdependent because a decrease in organic matter increases the susceptibility of a soil to erosion (Pierce and Lal, 1991). Changes in land management, such as the increasing implementation of no-till practices, may affect rates of organic matter loss (Coleman et al., 1983). Organic carbon will be used as a surrogate measure of organic matter.

6.8.1.2 *Clay Content*

Soil clay content is the weight percentage of the particle size class smaller than 0.002 mm diameter that is present in the <2 mm soil fraction. Clay may have thousands of times more surface area per gram than silt or sand and is, therefore, the most chemically and physically active part of the mineral soil (USDA-SCS, 1983). Under conditions of accelerated erosion, the more clayey subsurface soil layers (B horizons) are increasingly incorporated into the plow layer leading to marked textural changes of the surface A horizons (Indorante et al., 1991; Frye et al., 1982; Stone et al., 1985; Pierce and Lal, 1991). The implications of changing the surface soil texture on

crop productivity can be significant. The kind and amount of clay affects available water capacity, permeability, erodibility, and workability (Frye et al., 1982; Lal, 1987; Pierce and Lal, 1991). This parameter will be analyzed as part of the particle-size analysis performed on the soil samples. During the particle-size analysis, sand and silt contents will also be obtained.

Carbonate clays (i.e., the percent of the less than 0.002 mm diameter fraction) will be determined on soils with a pH > 7.0 and/or where free carbonates are indicated in the soil by the HCl drop test as indicated by the presence of sample effervescence. Carbonate clays are determined because they have different properties and chemical reactions in the soil than the other non-carbonate (silicate) clays. For example, the water holding capacity of a carbonate clay is approximately two-thirds that of non-carbonate clays (USDA-SCS, 1992).

6.8.1.3 Soil pH

Soil pH is an indicator of possible chemical constraints to the growth of roots and other biological communities. Chemical constraints usually associated with pH include the availability of inhibitory compounds (e.g., aluminum, salts), or a nutrient deficiency (e.g., phosphorus fixation), (Pierce and Lal, 1991). As soil weathering and leaching processes progress, base cations are removed from soil and the pH declines. The amount of rainfall, rate of percolation, and evaporation leave a definite impression on pH and on the morphology of the soil profile. An increase in acreage of land in either highly acid *or* highly alkaline classes would be interpreted as a warning of decline in soil quality.

6.8.1.4 Electrical conductivity/Salinity

Salinity is the concentration of dissolved salts in water. High concentrations of neutral salts, such as sodium chloride and sodium sulfate, may interfere with the absorption of water by plants through the development of a higher osmotic pressure in the soil solution than in the plant cells. Salts may also interfere with the exchange capacity of nutrient ions, thereby, resulting in nutrient deficiencies in plants (USDA-SCS, 1983). An increase in the proportion of soils in a region with high salinity would be interpreted as a warning of decline in soil quality. If the electrical conductivity of the sample exceeds 2.5 S/m, soluble salt contents will be quantified.

6.8.1.5 Calcium Carbonate Equivalent

In some soils of Nebraska, naturally occurring carbonates may be found in surface and subsurface horizons. The distribution and amount of $CaCO_3$ are important for fertility, erosion, and available water holding capacity of the soil. High $CaCO_3$ content at or near the soil surface can be an potential indicator of erosional loss of the original soil surface horizons. The loss of $CaCO_3$ from the soil at depth may indicate acidic inputs from either natural decomposition of organic matter, anthropogenic inputs of fertilizers (e.g. urea), and/or atmospheric deposition.

6.8.1.6 Cation Exchange Capacity and Exchangeable Cations

The cation exchange capacity (CEC) of a soil is defined as the sum total of exchangeable cations that a soil can adsorb (USDA-SCS, 1992). The CEC is a reversible reaction in the soil solution and may arise from permanent charges or pH-dependent sites on organic and mineral matter (predominantly of the clay minerals, although some CEC resides on silt-sized particles). Since the CEC is dependent upon the negatively charged sites of organic and mineral matter, any loss of organic matter, silt, and/or clay content will lead to a decrease in the CEC of the soil and may indicate accelerated soil erosion or poor tillage practices that leave the soil susceptible to erosion by wind or water. Conversely, a sudden increase in the CEC of the surface horizons may be an indication of erosional loss of the natural A horizon or deep tillage practices, both of which lead to the subsequent incorporation of subsurface material into the topsoil.

Exchangeable cations are those positively charged elements which are readily exchanged from the charged sites in a soil. The exchangeable cations generally include: Ca, Mg, K, and Na. They are commonly used to characterize the soil fertility status and thus provide information on readily available plant nutrients. Exchangeable cation contents are also used in the calculations of other parameters including: percent base saturation, sodium adsorption ratio (commonly used to determine the quality of irrigation water in relation to Na/salt buildup in the soil), and exchangeable sodium percentage (used to indicate high Na content in the soil which leads to detrimental plant effects such as osmotic stress, specific ion effects, and nutritional imbalances).

6.8.1.7 Extractable Phosphorus

Phosphorus is a macronutrient that directly effects plant growth and health and is thus, a common component in fertilization program on any given field. Conversely, phosphorus in excess quantities that reaches a stream, pond, or lake via overland runoff or reaches the groundwater via leaching is a common fresh water pollutant. In the soil, phosphorus is generally strongly bound to the soil particles in the subsurface horizons but has a relatively slow release rate through time. Over the years of standard phosphate fertilizer application, the potential for the creation of a large pool of P in the subsurface horizons of soil exists. Thus, in the agriculture system, the monitoring of P in the subsurface horizons can indicate if P is accumulating and could become a potential pollutant when released during erosion events or leached into groundwater, if P contents are remaining at steady concentration levels, or if P is being 'mined" by the plant uptake through time.

6.8.1.8 Aggregate Stability

An aggregate is a group of primary particles that cohere to each other more strongly than to the surrounding soil (USDA, 1992). Aggregate stability is a function of whether the cohesive forces between the particles can withstand the applied disruptive forces, such as plowing and raindrop impact. Aggregate stability is influenced by soil particle-size distribution, clay mineralogy, structure, organic matter content, and microbial population. Erodibility of the soil increases as aggregate stability decreases, thus, this parameter can be used to as an indicator of soil erosion potential and the "physical health* of the soil.

6.8.1.9 Available Water Capacity/Water Retention Difference

Available water capacity (AWC) is the capacity of a soil to hold water available to plants. AWC is commonly presented as the water retention difference (WRD) WRD is the amount of water held by the soil at tensions between field capacity and permanent wilting point (-1500 and size distribution of the soil.

6.8.1.10 Bulk Density

Bulk density is the parameter most closely related to mechanical impedance of root growth in models that relate soil properties to soil productivity (Kiniry et al., .1983; Pierce et al., 1983). Crop rotation and soil management of a given soil affects the bulk density, especially of the surface layers. Accelerated erosion and intensive cultivation increases bulk density; adding crop residues, manure or planting cover crops tend to lower it (Frye et al., 1982; Brady, 1974; Groenevelt et al., 1984).

Nonlimiting critical and root-limiting bulk densities are generally known and vary with the texture class of the soil (USDA-SCS, 1975; Pierce et al., 1983). An increase in the proportion of soils reaching critical bulk density values within their texture class is interpreted as an indication of declining soil quality. Bulk density is thus an important component in a soil structure index. Bulk density can also be used to convert analyte concentrations from a weight to a volume basis.

6.8.7.11 Soil Porosity

The pore space of a soil is that portion occupied by air and water. Continuous cropping, particularly of soils originally high in organic matter, often results in a reduction of pore space. The reduction is usually associated with a decrease in organic matter content and a consequent lowering of granulation and soil structure (Brady, 1974). Conversely, when conservation, no-till, or other reduced tillage practices are employed, the opposite effect may be seen with an increase in soil porosity through time. Porosity of a soil is generally calculated from the results of the bulk density determinations at varying water contents (-33 kPa and the particle density of the sample).

6.8.2 Data Sources

Data for a majority of the soil quality parameters (excluding erosion) will come from the analysis of soil samples taken by either the NASS enumerators or SCS soil samplers. Sampling protocols for both types of samples are presented in sections 3.3.2.1 and 3.3.2.2 for NASS and SCS, respectively. NASS-collected surface samples will be analyzed to determine clay content (particle-size distribution), organic carbon, pH, CEC, exchangeable cation contents, extractable

phosphorus, and calcium carbonate equivalence (in soils with pH > 7.0). The "special" samples collected by the SCS will undergo the same analyses as the NASS-collected samples but also will undergo analysis for available water capacity, aggregate stability, bulk density, and 15 bar (-1500 kPa) water retention.

The soil erosion tolerance factor (T) is also available from the SCS State Soil Survey Database (SSSD) (USDA, 1989). The T factor is defined as the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely (USDA, 1975). There are five classes of T factors, ranging from two kilograms per hectare (tons per acre) per year for shallow or otherwise fragile soils to eleven kilograms per hectare (tons per acre) per year for deep soils that are least sensitive to damage by erosion.

6.8.3 Quality Assurance for Field Measurements

Data quality for the soils properties indicator is a function of both the field activities and the analyses in the USDA-SCS National Soil Survey Laboratory in Lincoln, Nebraska. The EMAP-Agroecosystem QA Program addresses both of these components which are described in the following subsections.

6.8.3.1 Field Precision

Two sources of field variation (error) will be examined and assessed during the collection of soil samples by NASS, namely, large-scale heterogeneity across a given field and short-range heterogeneity within a given composite sample. To assess the natural variability of the entire measurement system (i.e., the large-scale heterogeneity), on every sixth field, a second complete transect will be collected and composited to form an additional second sample. The collection method will be identical-to the first transect sampled except that the entry into the field will be from a different starting point (e.g., field corner). This sample, the field duplicate (FD), will be collected following the standard sampling protocols described in Section 3.3. Both duplicate samples will be submitted to the analytical laboratory for analysis as two unique, double-blind (neither the sample identity nor analyte concentration known to the laboratory), replicate samples.

To assess the error component associated within a given composite sample (NOTE: a composite sample in this case is composed of the forty 20-cm core samples placed in the sampling bucket, disaggregated by hand, and mixed), field split (FS) samples will be collected from every twelfth field. Upon completion of the field preparation, the sample will be divided into approximately two equal portions. Both portions will be submitted to the analytical laboratory for analysis as two unique, double-blind, replicate samples. The split samples also will allow for the assessment of the effectiveness of the in-field sample preparation process as it relates to potential differences that may occur during subsampling the aliquots for nematode identification and enumeration and for soil physical and chemical characterization. Additional detail on the sampling procedure may be found in Section 3.3.

6.8.3.2 Sample Identification in the Field

For each field, the NASS enumerator will be given the following information printed on an instruction sheet placed within their questionnaire package: the sample number(s), whether or not a second composite sample must be collected in that field, the number of cores to be collected from each transect, and the number of paces along and into the field to determine the midpoint of the sampling transect. Additional labels, each with a different identification number, will be provided for composite samples that will be collected as duplicate samples or divided into split samples. All labels will be printed in cooperation with the Nebraska State Office of NASS.

6.8.4 Quality Assurance for Laboratory Measurements

To date, it has not been feasible to provide a single type of measurement quality sample whose variability is a concise and reliable estimate of overall measurement uncertainty. However, the combination of two or more types of measurement quality samples, which include the quantifiable components of system measurement uncertainty, can provide a reasonable and defensible estimate of overall data quality. The design of QA measurement quality samples has been based on several assumptions:

- Measurement uncertainty at any given phase requires a minimum number of n in order to be confidently evaluated. EMAP-Agroecosystem will attempt to optimize QA adequately in both the field and analytical phases in order to meet statistical requirements.

- The primary sources of measurement uncertainty to be identified, controlled, and evaluated are field sampling, sample preparation, and sample analysis.

- Each of the primary sources of uncertainty may be considered to be a combination of several smaller sources of uncertainty, e.g., the analytical component for the 1993 pilot study can consist of among-batch, within-laboratory, and within-batch uncertainties. Within each batch, a variety of measurement quality samples are included to evaluate and, possibly, control various types of measurement uncertainty. For each soil parameter measured, these samples have certain specified criteria that must be satisfied before the batch data are accepted. These samples may originate from many different sources and may be introduced at different phases of the measurement system. Types of measurement quality samples used in the soil measurement system include reference, laboratory duplicate, calibration check, and reagent blank samples. Collectively, the samples can be used to assess variability or adherence to the field and laboratory protocols, and to evaluate whether the MQOs have been met for any given run or batch of samples, or for all batches, i.e., overall measurement uncertainty. A series of these samples must be analyzed together with the routine samples in a statistically relevant manner from which conclusions concerning the quality of data can be made.

6.8.4.1 Laboratory Quality Assurance Samples

Quality assurance samples are double-blind samples submitted to the laboratory to assess both accuracy and precision. In addition to the two field precision samples (Section 6.8.3.1), the following DA samples will be used to estimate precision and accuracy of the soil preparation and analysis phases of the 1993 laboratory activities. [NOTE: Both the sample preparation and analysis for the EMAP-Agroecosystem samples will be performed by the USDA-SCS National Soil Survey Laboratory in Lincoln, NE. During the following discussions, the preparation and analytical

areas of the laboratory will be identified as the preparation laboratory and analytical laboratory, respectively.]

- Preparation Laboratory Duplicate (PLD) Sample - one PLD soil sample is split from a randomly selected routine sample during sample preparation as part of the homogenization/subsampling procedure. This pair of samples (the routine and its PLD) is placed in each sample batch of routine samples to estimate the preparation laboratory contribution to the measurement system uncertainty. The PLD characterizes the measurement error introduced during or after the homogenization/subsampling procedure at the preparation laboratory, but does not identify the error or contamination introduced during the sample drying, sieving, or any other activity occurring prior to sample homogenization. These samples serve for precision estimates. The identity of the PLD samples should only be known to the preparation laboratory manager and will be supplied to the EMAP-Agroecosystem QAC after preparation of each batch. The identity of the PLD samples should be double-blind to the analysts and analyses should occur at the rate of one PLD per analytical batch.

- Reference Sample (RS) a median concentration soil reference sample will be submitted by the laboratory CA staff to the preparation laboratory manager for inclusion in each batch of samples submitted for analysis. The RS is used to estimate the analytical within-batch accuracy. Further, by comparing the RS across batches allows the CA staff to estimate the among-batch component of analytical measurement uncertainty. This sample thus serves for both precision and accuracy estimates. At this time, the EMAP-Agroecoayatem does not have ita own RS. Attempts will be made by the EMAP-Agroecosyatem QAC to obtain a reference sample from the EMAP-Forest group for inclusion in the EMAP-Agroecosystem analytical batches. Plans are currently being made to collect and characterize soil samples by the ARG (Campbell et al., in prep.1 for the EMAP-Agroecosystem program. These samples will be collected during the 1993 Agroecosystem Pilot Field Program and will undergo initial characterization (as double-blind samples) along with the routine samples during this pilot.

6.8.4.2 Laboratory Quality Control Samples

Quality control samples are samples whose identity, and sometimes concentrations, are known to the analytical laboratory personnel. The following QC samples will be used by the USDA-SCS National Soil Survey Laboratory to assess and control potential sample contamination, precision, and accuracy.

- **Laboratory Duplicate (LD) Sample - A duplicate subsample of the 25th soil sample in each batch (or the last sample if the batch is smaller than 25 samples) is selected as the LD sample at the analytical laboratory and is used as an internal check to ensure that predefined within-batch precision MQOs are being satisfied as defined in the batch acceptance criteria. If duplicate values fall outside of control limits, an explanation must be sought, e.g., instrument malfunction or calibration drift. A second, different sample must then be analyzed in duplicate. Routine sample analysis should cease until duplicate sample results are within the control limits, at which time the batch of samples may be reanalyzed for the parameter in question.**

- **Reagent Blank (RB) - For each extraction or instrument run, a series of RB samples are prepared and analyzed as part of the batch. The RB is defined as a liquid (or occasionally soil) sample composed of all the reagents in the same quantities as those used in preparing an actual sample for analysis. The reagent blank undergoes the same digestion and extraction procedures as an actual sample, and, therefore, should reflect any analyte contamination inherent from the extraction procedure. Three RB samples per batch are analyzed: at the beginning, in the middle, and at the end of each batch, and are reported for each batch. For most parameters, the analyte concentration of an RB sample must satisfy detectability requirements (i.e., must be below the detection limits).If not, the source of contamination must be investigated and eliminated, and a new reagent blank prepared and analyzed. All samples associated with the "high* blank must be reprocessed and reanalyzed after the contamination has been eliminated.**

- **Calibration Check (CC) Sample --The CC is a usually a liquid (or occasionally solid) sample containing the analyte of interest at a concentration in the mid-calibration range.**

Approximately five CC samples per batch are analyzed to verify the calibration curve: once at the beginning of sample analysis, after every 10 samples, and after the last sample of a batch. The CC must be prepared or selected from a stock solution different than that used for the instrument calibration, or it may be obtained commercially. The CC data are evaluated on a control chart by the laboratory manager. The same CC stock solution must be used to establish all values on a given control chart to ensure continuity. A value outside of the control limits (99 percent confidence interval) is considered unacceptable. In this event, the instrument is recalibrated and all samples up to the last acceptable CC are reanalyzed. After each day of analysis, the control charts are updated by calculating cumulative mean values and new warning/control limits (± 2 and 3 standard deviations). If bias is indicated, i.e., at least seven successive points occur on one side of the cumulative mean, sample analysis must cease until an explanation is found and the system is brought under control for the parameter of interest.

For balances, the CC sample is a 'S* class weight if the total sample weight is <200 g or a "P" class weight where total sample weight is 2200 g. The CC weight selected should be within the calibrated range of the analytical or top-loading balance. No control charting for these determinations is required. CC samples should be run at the beginning, middle, and end of each batch of samples.

For particle-size analysis, the SCS laboratory, in conjunction with the balance check described above, includes an 'internal soil* for the determination of bias and as a check on the calibration of the analytical system. The "internal soil" is a soil that has been highly characterized by the SCS and thus serves as a reference-like sample. Control charts m updated every six months. The SCS laboratory will provide the EMAP-Agroecosystem QAC with a copy of the control chart clearly delineating the time frame in which EMAP-Agroecosystem samples were analyzed.

- Detection Reference (DR) Sample - For non-gravimetrically determined parameters, a DR sample will be analyzed with each batch of soil samples. This sample is a low concentration soil sample that contains the analyte of interest at a concentration that is typically two or three times above the MDL. The primary uses of the DR sample are for

the estimation of actual levels of detection at the laboratory and to check for significant baseline drift. Each measured DR sample concentration must be within ± 20% of the known value. If not, the source for error must be identified, corrected, and an acceptable result must be obtained before routine sample analysis is resumed.

6.8.4.3 Methodology and Detection Limits

Table 6.3 provides a listing of the methods selected for each of the soil indicator parameters to be analyzed in the HAP-Agroecosystem program.

Method detection limits (MDLs) for the EMAP-Agroecosystem program are defined as 3 times the standard deviation of the measured concentration of 15 or more blanks or low-level standards whose concentrations are within a factor of 10 of the detection limits presented in Table 6.3. MDLs should be determined prior to analysis of the first batch of routine samples and should be determined for each instrument or apparatus used for the analyte concentration quantification. The MDL determined from this analysis is applicable to all samples analyzed within a one month period following the initial determination. A new MDL must be determined each month the analysis are being performed for each instrument or apparatus used for the analyte concentration quantification.

Method detection limits for top-loading or analytical balances (sample weights <200 g) used during sample aliquoting are determined by the placement of a 0.010 g 'S* class weight on the balance after successful initial calibration. The final reading should be within 0.010 f 0.001 g. For bulk soil weighing in the preparation laboratory (e.g., for bulk density, aggregate stability, and available water capacity) where the total sample weight is ≥200 g, 2-100 g 'S* class weights will be used to determine the MDL. The final weight should be 200 ± 0.05 g.

6.8.4.4 Initial Calibration

Initial calibration, where appropriate, for all analyses performed in the EMAP-Agroecosystem program should be completed using a minimum of a three-point curve or following the instrument manufacturer's instructions. The acceptance criteria for the initial three-point calibration curve,

Table 6.3 Methods for soil samples analyses in the EMAP-Agroecosystem program.

Parameter	Selected Method	Detection Limit	Reference
Sample Preparation	1B1	N/A[a]	USDA-SCS, 1992
pH	8C1f	N/A	USDA-SCS, 1992
Organic Carbon	6A2	0.03 %	USDA-SCS, 1992
Electrical Conductivity	8I	0.1 dS/m	USDA-SCS, 1992
soluble salts[b]	8A3	0.01 meq/L	USDA-SCS, 1992
Cation Exchange Capacity	5A8	0.15 meq/100 g	USDA-SCS, 1992
Exchangeable Cations			
Ca	6N2e	0.01 meq/100 g	USDA-SCS, 1992
Mg	6O2d	0.01 meq/100 g	USDA-SCS, 1992
K	6Q2b	0.01 meq/100 g	USDA-SCS, 1992
Na	6P2b	0.01 meq/100 g	USDA-SCS, 1992
Extractable Phosphorus	modified 6S3[c]	0.05 mg/kg	USDA-SCS, 1992
	24-5.4[d]	0.05 mg/kg	Olsen and Sommers, 1982
$CaCO_3$ Equivalence	6E1	0.1 %	USDA-SCS, 1992
Carbonate Clays[d]	3A2d	0.1 %	USDA-SCS, 1992
Aggregate Stability	4G1	0.010 g	USDA-SCS, 1992
Bulk Density	4A1	0.010 g	USDA-SCS, 1992
Available Water Capacity	4C1	0.010 g	USDA-SCS, 1992
Particle-Size Analysis	3A1	0.001 g	USDA-SCS, 1992

a - N/A = not applicable.
b - soluble salts only analyzed if electrical conductivity > 2.5 S/m.
c - method will be modified to Bray II extraction procedure.
d - analyses only performed when indicated by effervescence in 1 N HCl drop test.

a calculated coefficient of determination (R^2) of $\geq$ 0.97. The initial calibration range should cover the expected concentration range of the routine samples. If the initial calibration range is exceeded by a routine sample, a new calibration curve, with an expanded range, must be established and the samples exceeding the range, re-analyzed.

For samples/aliquots with weights <200 g, the balance must be calibrated to cover the sample weight range using at least two different "S" class calibration weights. All weights should be within $\pm$ 0.001 g of the known weight. For samples with weights $\geq$200 g, initial calibration will be performed at least two "P" class weights that cover the range of sample weights. All "P" class weights should be within the tolerances indicated in the manufacturer*s specifications for the individual weight.

All instruments used in the EMAP-Agroecosystem program must be calibrated prior to analysis of any EMAP-Agroecosystem samples.

6.8.4.5 Measurement Quality Objectives

The field precision requirements for the EMAP-Agroecosystem program is that the RPD between the duplicate or split samples should be s 15%. Field duplicate and split samples are required for all soil parameters.

The analytical precision requirements for the EMAP-Agroecosystem program for the laboratory duplicate and the preparation laboratory duplicate is that the RPD between the duplicate and its corresponding routine sample should be ≤ 10%. Analytical duplicates are required for all soil parameters, excluding bulk density. Bulk density samples are prepared (saran-coated) in the field and no replication at the laboratory is possible without the destruction of the original sample integrity.

The calibration check samples are used to assess the accuracy of the instrument and verify the calibration curve. An accuracy of ± 10% of the known value is required for the CC samples with the exception of Bray II P in which the accuracy must be within ± 15% of the known value. In the case of pH, an accuracy of ± 0.05 pH unit is required from a standard from a different stock solution lot than that used for the initial calibration of the pH meter. For all balances, where the CC sample is a "S" class weight (see section 6.8.4.2), the acceptance criterion is ± 0.001 g of the known value. For balances where the CC sample is a "P" class weight (see section 6.8.4.2), the weight obtained from the balance must be within the manufacturer*s specifications for each weight.

In the situation where a reference sample is obtained from the EMAP-Forest Program, the accuracy of the parameters must fall within the accuracy windows provided by the QAC of EMAP Forest Program. The accuracy windows for reference samples within the EMAP-Forest program are constantly being updated as more data are obtained. The EMAP-Agroecosystem QAC will obtain a

copy of the most recent accuracy windows for determining the acceptability of the reference sample results.

Reagent blanks should have concentration values below the method detection limits of the instrument or apparatus. Reagent blanks are appropriate for all soil indicators excluding pH, bulk density, aggregate stability, soil porosity, and available water content. Within the determination of the particle-size distribution of a soil, a reagent blank analysis is performed. The reagent blank is used to correct for the weight addition of the dispersing agent. In this case, the reagent blank is not subject to the QA requirement of being less than the detection limit.

The completeness MQO for all soil indicator data has been set at 90%.

6.8.4.6 Batching of Soil Samples for Analysis

Soil samples will be shipped and received by the USDA-SCS National Soil Survey Laboratory from either the NASS enumerators or the SCS soil scientists. Samples will be mailed directly to the analytical laboratory the same day they are collected or first thing the next morning through Federal Express or United Parcel Service. Samples may be processed (dried, disaggregated, sieved, and checked for the presence of free carbonates) following method 1B1 of the *Soil Survey Laboratory Methods Manual* (USDA-SCS, 1992). Once 40 or more samples have been received and processed, an analytical batch of samples should be prepared which includes all the appropriate QA/QC samples described in sections 6.8.4.1 and 8.8.4.2. The final batch size should be 40 $\pm$ 2 samples. This batch may then be submitted to the analytical laboratory for analysis. The final batch of samples to be processed by the laboratory may contain less than 40 samples. The ARG will inform the preparation laboratory when all the field samples have been collected and shipped to prevent delays at the laboratory during the processing of the final, potentially smaller, batch of soil samples.

6.8.5 Information Management, Data Verification, and Validation

The analytical data will be entered into an electronic data base at the SCS laboratory and subjected to the USDA-SCS National Soils Laboratory*s internal QC checks and verification

procedures. The data will then be sent on diskette and in hard copy to the EMAP-Agroecosystem Information Management Center where it will be checked and will become part of the permanent database. The indicator lead will review all the data for content and completeness.

6.9 Soil Biotic Diversity Research indicator

Indices of nematode community structure show promise for monitoring the biological condition of soils because of their central position in soil food webs (Moore and de Ruiter, 1991) and ability to detect change in soil condition (Bangers, 1990; de Goede, 1993; Ettema and Bongers, 1993; Freckman and Ettema, 1993; Neher et al., 1994). As other biota, nematodes respond to changes in environmental conditions. Perturbation, such as addition of mineral nitrogen fertilizers (Wasilewska, 19891, cultivation (Hendrix et al., 19861, liming (Hyvonen and Persson, 1990), and addition of heavy metals (Bangers et al., 1991; Samoiloff, 1987) to soils, affects species richness and trophic structure (Wasilewska, 1989).

The nematode community indicator will be evaluated for its ability to answer the assessment question, "What proportion of agroecosystem units has soils than cannot support diverse communities of soil microbiota?" The specific questions to be answered by the Region VII pilot are:

- Is nematode community structure similar between Region VII and Southeast agroecosystems? An, the population distributions of index values (e.g., maturity index, diversity index) comparable between the two areas?

- Does the variance among regions, among fields, and within fields for this assessment endpoint allow data quality objectives to be met with a reasonable sample size?

- Are the indices of nematode community structure which indicate soil biological health generally applicable? Are the soil properties that influence nematode density and community structure the same between Region VII and the Southeast? Is the relationship between the soil environment and nematode community structure similar in the two areas?

- **Do permanent pastures have significantly different nematode community index values and can they be used as a reference base for comparison of soils with annual crops?**

6.9. 1 Soil Biotic Diversity Measurements

A total of 270 soil samples from the NASS Rotational Panel Sampling Plan Design described in Section 3.2 (including duplicates and split samples for QA/QC purposes) plus 20 permanent pastures will be analyzed for nematode communities. NASS enumerators are responsible for the collection of the field samples following procedures specified in Section 3.3.2.1. The N & A Nematode Identification Service in Davis, California, will classify and count nematodes.

Additional supplementary data will be collected for the soil biotic diversity indicator from varied sources. Nematode habitat information data will be measured by quantifying organic carbon, exchangeable calcium, exchangeable sodium, pH, electrical conductivity, texture (particle-size distribution), and gravimetric moisture content from the same composite soil sample from which the nematodes sample was originally obtained (see Sections 3.3.2.1 and 6.8). These data will be obtained from the EMAP-Agroecosystem soil quality indicator lead.

Supplementary data concerning: 1) application of nematicides, by trade name and formulation; 2) crop(s) planted; 3) cropping history; and 4) tillage practices will be collected during the NASS verbal Fall Survey for the EMAP-Agroecosystem program. A complete copy of the NASS survey questionnaires can be found in *the 1993 Agroecosystem Pilot Field Program Plan* (Campbell et al., in prep.).

6.9.2 Quality Assurance Measurements for Soil Biotic Diversity Indicator

Data quality for the soil biotic diversity indicator is a function of both the field activities and the analyses at N&A Nematode Identification Service in Davis, California. The EMAP-Agroecosystem CA Program addresses both of these components which are described in the following subsections.

6.9.2.1 Field Precision

Two sources of field variation (error) will be examined and assessed during the collection of the soil samples, namely, large-scale heterogeneity across a given field and short-range heterogeneity within a given composite sample. To assess the natural variability of the entire measurement system (i.e., the large-scale heterogeneity), on every sixth field, a second complete transect will be collected and composited to form an second sample. The collection method will be identical to the first transect sampled except that the entry into the field will be from a different starting point (e.g., field corner). This sample, the FD, will be collected following the standard sampling protocols described in Section 3.3. Both duplicate samples will be submitted to the analytical laboratory for analysis as two unique, double-blind (sample identity unknown to the laboratory), replicate samples.

To assess the error component associated within a given composite sample (NOTE: a composite sample, in this case, is composed of the twenty 20-cm core samples placed in the sampling bucket, disaggregated by hand, and mixed), FS samples will be collected from every twelfth field. Upon completion of the field preparation, two samples for the soil biotic diversity indicator will be collected prior to the division of the remainder of the sample for the soil quality indicator field split samples. Both potions will be submitted to the analytical laboratory for analysis as two unique, double-blind, replicate samples. The split samples also will allow for the assessment of the effectiveness of the in-field sample preparation process as it relates to potential differences that may occur during subsampling the aliquots for nematode identification and enumeration. Additional detail on the sampling procedure may be found in Section 3.3.

6.9.2.2 *Sample Identification in the Field*

For each field, the NASS enumerator will be given the following information printed on an instruction sheet placed within their questionnaire package: the sample number(s), whether or not a field duplicate and/or field split sample must be collected in that field, the number of cores to be collected from each transect, and the number of paces along and into the field to determine the midpoint of the sampling transect. Additional labels, each with a different identification number,

will be provided for composite samples that will be collected as duplicate samples or divided into split samples. All labels will be printed in cooperation with the Nebraska State Office of NASS.

6.9.3 Quality Assurance for Laboratory Measurements

Quality assurance samples are double-blind samples submitted to the laboratory to assess accuracy and precision of the nematode taxonomic identifications. In addition to the two field precision samples (Section 6.9.2.1), secondary confirmation of nematode taxonomic identifications will be performed. If available, a second qualified nematode taxonomist will be asked to repeat the identifications on approximately 10% of the enumerated samples. If discrepancies are found between the nematode identification, a conference call will be held among the EMAP-Agroecosystem soil biotic diversity indicator lead and the two taxonomists to resolve the differences. Where differences are unresolvable, the EMAP-Agroecosystem soil biotic diversity indicator lead will make the final decision.

6.9.4 Quality Control for Laboratory Measurements

Quality control samples are samples whose identity are known to the analytical laboratory personnel. A LD subsample of the 20th soil sample is selected as the LD sample at the analytical laboratory and is used as an internal check to ensure that predefined within-batch precision MQOs are being satisfied as defined in the batch acceptance criteria. Both the biological identifications of the organisms present (by taxa) and examination of the relative abundance of nematodes identified will be assessed. If duplicate values fall outside of control limits, an explanation must be sought, e.g., high sample variability, misidentification of organisms. A second, different sample must then be analyzed in duplicate. Routine sample analysis should cease until duplicate sample results are within the control limits, at which time the batch of samples may be reanalyzed for the parameter in question.

6.9.5 Analytical Method

Typically, counts are made on 20% of the nematodes extracted from the 500-mL soil sample. For every 20th sample, identification and enumeration will be repeated: 1) on the same subsample (20% of total) and 2) on a second subsample from the same soil sample. These repeated measurements permit estimation of the components of variance associated with identification and within sample variability, respectively.

Nematodes will be extracted from soil using Cobb*s sifting and gravity method (Ayoub, 1980; Thorne, 1961) modified by triplicate passes through each 710 ,m-, 250 ,m-, 150 ,m-, 75 ,m-, 45 ,m-, and 38 ,m-mesh sieves. After sieving, the centrifugal-flotation method of Caveness and Jensen (1955) modified by using a 1:1 sugar solution (v:v) and centrifuging for 1 min will be used to extract nematodes from soil. Nematodes extracted from the 710 and 250 ,m sieves are pooled as a subsample for centrifuging as are nematodes extracted from 150, 75, 45 ,m sieves. SOPs for the modified Cobb*s sifting and gravity method and the modified sugar centrifugal-flotation method are presented in Appendices C and D, respectively. Classification of trophic groups will follow Yeates et al., (1993) and taxonomic classification of nematode families will follow Maggenti (1982, 1991).

A representative sample of nematode families from each sample will be preserved in 10% formalin in 25-mL vials with 0.5 to 1.0 mL of glycerin added and the vial sealed with paraffin wax and stored at room temperature (Daykin and Hussey, 1985). The preserved samples will be kept for four years and utilized if further information or confirmation is needed.

6.9.6 Measurement Quality Objectives

The precision estimates for the various trophic group and colonizer-persister values (Section 6.9.7) are presented for the field duplicate and field split in Table 6.4. Based on these preliminary data, the MQO for the field split and laboratory duplicate samples has been set to RPD $\leq$ 15%, while for the field duplicate samples, an RPD of 5 20% has been established.

A broad form of accuracy assessment can be made by examining the relative abundance and classification of the nematodes between replicate samples. A ranking of the most abundant through the least abundant nematode taxa will be performed. Agreement should be seen between the replicate samples for the top three taxonomic groups. Where disagreement is seen, a reexamination of the distribution is undertaken and possible explanations for the disagreement are sought, e.g., incorrect taxonomic identification, high sample variability.

6.9.7 Information Management, Data Verification, and Validation

The ARG will oversee data reduction, analysis and interpretation. The nematode laboratory will send completed data sheets (Campbell et al., in prep.) to the soil biotic diversity indicator lead who will supervise a research technician who will enter the data into a Lotus 1-2-3 spreadsheet on

Table 6.4 Preliminary data quality objectives for field split and field duplicate samples[a].

	Field Split Sample[b]		Field Duplicate[c]	
Parameter	SD[d]	%RSD[d]	SD	%RSD
Shannon[e]	0.27	3.04	0.16	7.37
MI[e]	0.06	9.27	0.48	15.64
PPI[e]	0.06	7.68	0.42	12.15

a - data quality objectives based on a preliminary experiment (Neher et al., 1994).
b - median values of 20 pairs of duplicate, composite samples from two fields.
c - average values for 30 composite samples collected for each of two fields .
d - SD = standard deviation; RSD = relative standard deviation.
e - Shannon = Shannon's index of diversity; MI = Maturity Index; PPI = plant-parasitic index.

a personal computer. The indicator lead will verify the data by comparing every entry in the computer with that on the original data sheet. Every entry on the hardcopy is checked for reasonableness.

Each identified nematode family will be assigned a trophic group and colonizer-persister (c-*D*) values (Campbell et al., in prep.). Diversity of taxonomic families and feeding preferences will be estimated using Shannon*s index of diversity and the successional status of nematode communities will be estimated using a Maturity Index of free-living nematodes (MI) and MI of plant-parasitic

nematodes (PPI) (Bangers, 1990). Trophic diversity will be estimated using the Shannon diversity index, (*N1*) where *N1* = exp [-GP_i(lnP_i)], and P_i is the proportion of trophic group *i* in the total nematode community (Ludwig and Reynolds, 1988). The MI is calculated as the weighted mean of the values assigned constituent nematode families (and the genera and species they contain): MI or PPI = (Gv_i * f$_i$) *In* where v_i = the colonizer-persister (c-*p*) value assigned to family *i, f*,= the frequency of family *i* in a sample, and *n* = total number of individuals in a sample (Bangers, 1990).

After necessary calculations and changes are made, two backup copies of the final data set will be downloaded to floppy disks. The final data set will include the following variables: sample number, MI, PPI, number of bacterivores, number of fungivores, number of omnivores, number of predators, number of plant-parasites, number of animal parasites, and Shannon*s diversity index values. Number of nematodes in each trophic group will be expressed as number per 500 mL of soil. The data will be combined with soil environment data under deputization by NASS at their State Office. The statistical analyses will be conducted using SAS or S + software. The soil biotic diversity indicator lead will be responsible for most of the data reduction and validation.

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Appendix A

Enumerator Manual for Soil Sampling

APPENDIX 3
ENUMERATOR MANUAL FOR SAMPLING SOIL

GENERAL

This section describes the procedures for collecting soil samples from the sample field for chemical and nematode analysis. Just as with information from the interview, all information is confidential. This includes any information about the soil collected from this field. The laboratories doing the analyses will not know where the samples were obtained or whose land they are from. Results of the analysis will be sent back to the Nebraska Agricultural Statistics Office within 6 months and from there they will be sent back to the farmer. Only authorized personnel will have access to this information.

Equipment to be taken into the field:
right angle
3 yellow stakes
10 red stakes
assembled probe
plastic bucket
screwdriver and/or wooden block with bolt
orange safety vest
disposable shoe covers (if required)

If any equipment is missing or breaks, call the State Office to request replacement parts. Parts can be delivered by Federal Express the following day.

Before entering the field:

1. Check the instruction sheet (Section IV) included in your enumerator kit to determine whether the field will be sampled in duplicate or not. Although most fields will have soil collected from only one sampling line, some fields will require soil from two different sampling lines. Also, some fields may have twice as much soil collected from a sampling line. How many sampling lines you will mark and how much soil will be collected from each is listed on the instruction sheet included in the enumerator kit for that field.

2. Place the record keeping label from the enumerator kit onto the back of the questionnaire.

3. Check the number of paces along and into field to determine the midpoint of the sampling line.

4. If this sample has also been selected for SCS soil samples, and the farmer has signed the consent form, record the rows and paces onto the consent form, so SCS soil scientists will be able to locate the sampling line again later. The starting comer,

rows, and paces and the location of the sampling line will also need to be drawn on the aerial photo.

I. LOCATING THE 5-ACRE SAMPLING AREA IN THE FIELD

The starting comer into the field will be the first comer of the field which is reached when approaching the field. If the field has NO definite comers, begin at the point which is most accessible by car. If the field is to have two sampling lines marked, the second closest comer will be the starting point for the second line.

Follow these procedures when locating and laying out sample units. You will locate the midpoint of the sampling line, then mark **out** and take samples from 10 places on each side of the midpoint.

STEP 1 Determine the starting comer. This will be the first comer you reach when approaching the field.

STEP 2 Walk along the end of the field the required number of rows as marked on the label. If there are no discernible rows in the field, count off paces instead of rows. This will be your entry point into the field. In the example in Figure 1 this is 12 paces. If the field border takes an abrupt turn, follow the border, but do not count paces that are <u>not</u> in the initial direction of walking. Continue counting once you are again moving in the starting direction (Figure 1).

STEP 3 Turn to face into the field and then walk the specified number of paces into the field. Start your first pace about one and one-half feet <u>outside</u> the plowed edge of the field. In Figure I this is 7 paces.

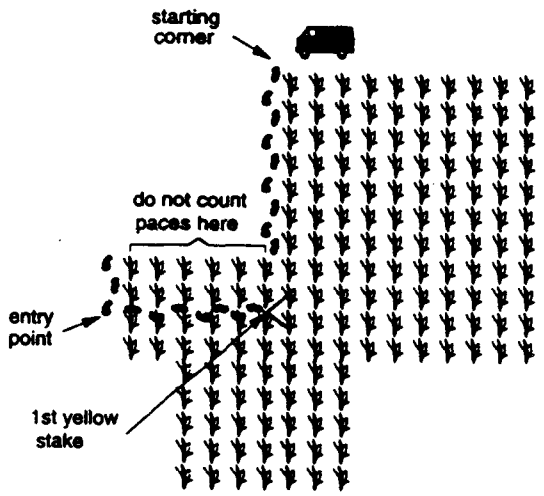

Figure 1. Starting point in odd-shaped fields.

IMPORTANT Do not count paces in any areas that are not considered cropland acres (stop counting at the start of each such area and resume counting at the other side). However, any blank or unplanted areas in the field that were not deducted should be included in the pace count.

*EXCEPTIONS *

1. Bounce back rule. When pacing along the edge of the field, or pacing into the field, if you reach the opposite end or side of the field and still have not taken the required number of paces, complete as many paces as you can until you are outside the field, then turn around and walk back in the direction from which you came until the required number of paces has been stepped off. (Remember to count both your exit and re-entry pace into the field.)

2. Odd-Shaped fields. The bounce back rule still applies. As in Figure 1, you should count paces along the field edge only while walking in the initial direction.

STEP 4 After you have taken the last of the required paces, you will mark out the center of the sampling line. Place a yellow stake at the toe of your shoe. Lay the right-angle on the ground with the point at the hinge touching the stake. Place a second yellow stake at the top right comer of the V (Figure 2).

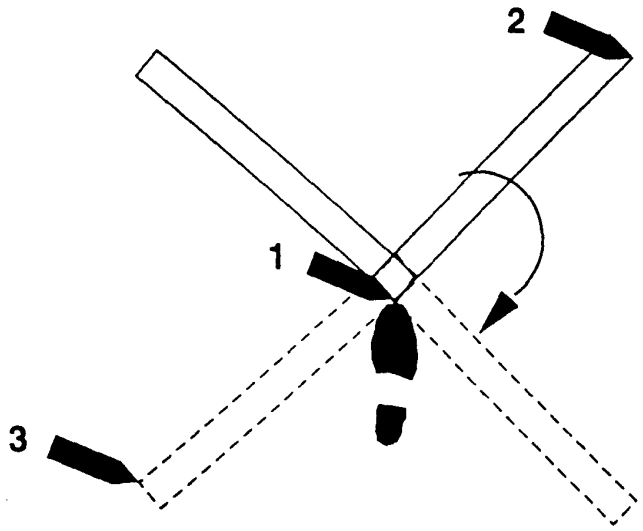

Figure 2. Placement of yellow reference stakes at center of transect.

STEP 5 Flip the triangle 180^0 so that it forms an upside down V with the hinge point still touching the stake. Place a third yellow stake at the bottom left comer of the right angle to form a straight line with all three stakes (Figure 2).

IMPORTANT Then pick up the right angle and 10 red stakes and carry them with you. You will need them as you pace off the sampling line.

STEP 6 Use the ten RED stakes to mark out the first half of the sampling line. Beginning at the center yellow stake, take two and one-half paces, along the straight line made by the three yellow stakes. Place a red stake at the toe of your shoe. This will be stake number 1.

STEP 7 Walk five paces from the stake and place a second red stake (stake 2) at the toe of your shoe.

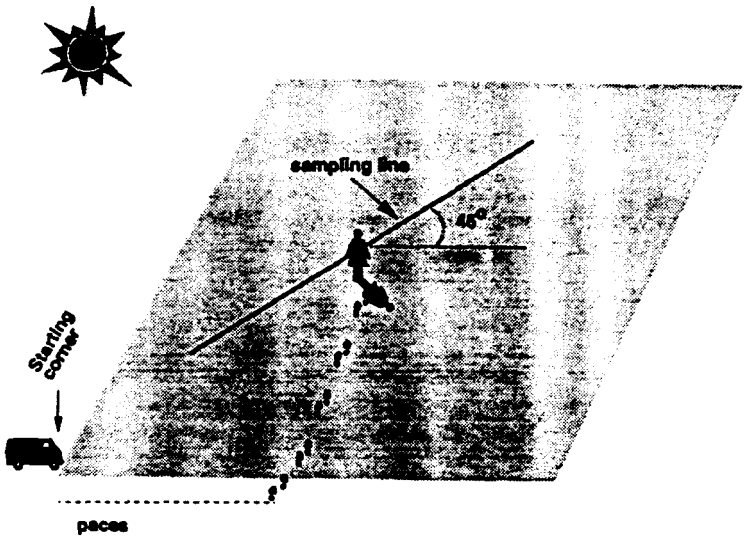

Figure 3. View of entire diagonal sampling line across the field.

STEP 8 Repeat step 7 until all 10 red stakes have been inserted into the soil. This line (called the sampling line) should be diagonal across crop rows (Figure 3).

IMPORTANT 90-Degree Rule. If you reach a border of the field while walking off the line, turn 90-degrees, so that you are again facing into the field and proceed with your paces and inserting stakes (Figure 4). Repeat the 90-degree rule for each border you reach. If the midpoint of the line falls on a comer or an edge use this rule to make sure both halves of the sampling line fall in the field.

STEP 9 Now that you have marked out 10 stakes you will turn around and take soil samples from each one until you are back at the yellow center stakes. To do this, first close the right angle. When closed, the right angle becomes a 3-foot ruler. Use it to measure off 3 feet from the last stake (number 10), and take one soil core (Figure 5). Instructions for taking the soil core begin in Section II below. In some fields, two cores will be taken from each stake. Instruction sheets in your enumerator kit will

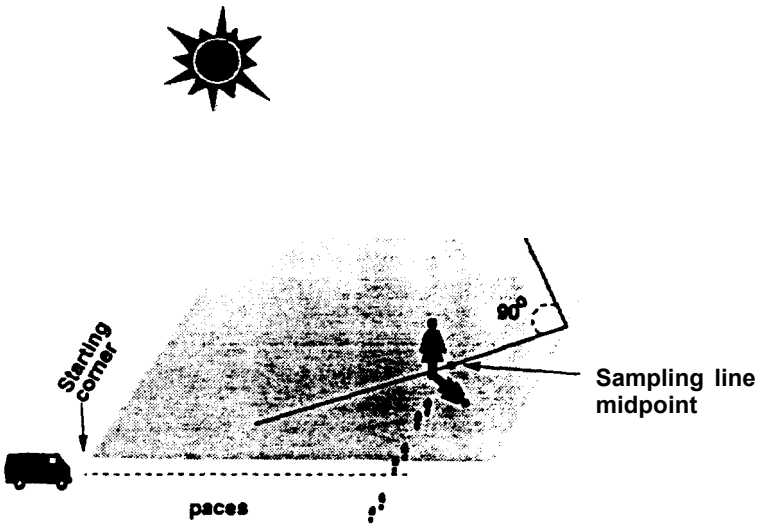

Figure 4. 90-degree rule for each border encountered.

tell you if double cores need to be taken.) Pull the red stake and place it in the bucket along with the soil after taking the soil core.

STEP 10 The right angle is also marked with a black line at 1.5 feet. Repeat step 9 at the next red stake except use the marking on the right angle to take the soil sample 1.5 feet from the red stake. Repeat this process at each red stake, alternating between taking samples 3 feet and 1.5 feet from each stake.

Stakes	Distance Soil Sample Taken From Stake
1, 3, 5, 7, 9	1.5*
2, 4, 6, 8, 10	3*

STEP 11 Once you have taken the ten samples (twenty for double sampled fields) from this half of the sampling line you will need to repeat steps 6 through 10, starting at the center yellow stake, walking in the opposite direction from the first half of the sampling line to pace out and take ten (again, twenty if double-sampled) cores at the ten points on the other half of the sampling line.

STEP 12 After taking the second set of ten soil cores, remove the remaining yellow stakes and exit field. (DO NOT remove all stakes for fields to be sampled by SCS, see note below.)

IMPORTANT AFTER bagging all the soil samples, make sure all stakes, soil probe, and bucket are free of soil before leaving the field area. Do not reuse

stakes in another field. If possible, rinse all equipment thoroughly with water at the farm. If you are taking samples 'from several fields it is important to keep any soil from one field from mixing with soil from another field. If you were wearing plastic "boots", remove them after all work in that field is complete.

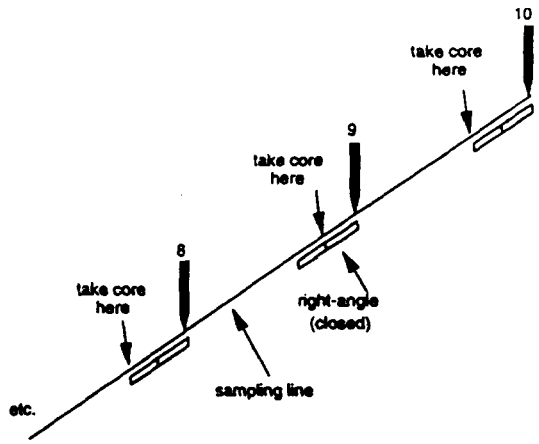

Figure 5. Even- and odd-numbered cores are taken 3* and 1.5*. respectively, from the yellow stakes.

Place them in a garbage bag for disposal in the garbage or at a landfill. Do not re-use them.

[*NOTE* FOR FIELDS SELECTED FOR ADDITIONAL SOIL CONSERVATION SERVICE (SCS) SAMPLES:

If the farmer has consented, SCS soil scientists will revisit these fields to take additional soil samples. SCS personnel will need to know where you took your samples, so tie some flagging ribbon at your starting comer. After you have taken your soil sample, DO NOT take all of the stakes out of the field. Leave the yellow stakes marking the center of the sampling line and the red stakes marking the ends of the sampling lines in the field. When you have finished, mark the rows, paces, starting comer and location of the sampling line on the aerial photograph. Deliver both the aerial photo and a copy of the consent form to the nearest SCS office.]

II. TAKING THE SOIL SAMPLE

For each core, push the soil probe *straight* down into the soil, without twisting, to the depth that fills the length of the tube (8"). Pull up the tube and push it down onto the bolt (in wooden block) to empty the core into the bucket; if soil sticks, a large screwdriver may be necessary to scrape the core out of the tube. If the core is less than 8" in depth, take another core within 6" of the same location. If there is heavy residue on the field push it aside with your foot before inserting the probe, but do not scrape the surface of the soil. Record any problems on the survey form. Combine all 20 cores from the sampling line in the bucket.

If you pull the probes from the ground and see that the core is less than 8" in depth, discard that core and take another within 6" of the same location. If you are still unable to get an 8" core then a 6" core is acceptable. If after several tries you cannot get even a 6" core, collect two 4" deep cores. Cores. MUST be at least 4" in length. If it is impossible to get even a 4"

core, do not take that sample, record that point as missing and move on to the next red stake. DO NOT take more cores elsewhere to "make up" for the loss. Record any problems on the survey form. Combine all cores from the sampling line in the bucket.

NOTES:

1. In the probe set, three tips will be available for the core tube for sampling soil under a range of conditions. The regular tip (with 2 notches on the rim), should be used for most soils. If the soil is especially dry or stony you may want to use the mini tip (1 notch) or super duty tip (3 notches). A thin metal rod for changing tips is included in each probe set, although a pair of vice grips may also be useful. Decide if you need another tip before you begin sampling. You will probably not want to change them very often; they are not easy to change.

2. Discard any rocks larger than 1" diameter. Do not remove plant or other organic debris from the soil surface, but keep as part of the sample. You may push heavy crop residue away with your foot, but do not scrape the soil surface as you do it.

3. If the soil is waterlogged, do not take nematode samples. Come back to the field at another time. Saturated soil in the plastic bag can become anaerobic (no oxygen) and the nematodes may die.

III. LABELING AND TRANSPORTING THE SAMPLE

When all cores have been deposited into the bucket for 1 composite sample, use your hands to break up the clumps gently (rough treatment of the soil may kill organisms living there) to clumps about l/4" or less in diameter. Mix the soil thoroughly. Two different size bags are included in your enumerator kits for sending soil for laboratory analysis. The larger bags will be used to hold soil for chemical analysis. The smaller bags will be sent to a different laboratory for nematode analysis.

Note: The following directions apply to the NAS1 type samples. Variations are discussed below.

From the bucket of mixed soil, fill the plastic beaker all the way to the top with soil and pour into a small plastic bag. Close the bag with a wire tag marked with the appropriate sample number. Pour the rest of the soil into the large bag and close it with another wire tag with the appropriate sample number. Do not write on the tag. To ensure confidentiality, no identifying information about the operation (such as names ***or*** addresses) will be associated with the samples sent to the laboratory.

IMPORTANT Place the record keeping label for each sample on a record keeping form and fill in the completion code. Also indicate whether the field

was cultivated or not. A field is considered cultivated unless it contains untilled stubble or a standing crop. Also enter the date the sample was taken, the date it was mailed and the Federal Express airbill number found on the shipping label. (The Federal Express airbill number is 10 digits and is located in the upper right hand corner of the airbill). Mail the record keeping forms and pink customer copies from the back of Federal Express airbills to the State Office with your completed questionnaire.

Store all samples in the cooler (in the shade!) at all times to avoid temperatures lethal to soil organisms!

Mail the beaker (small) sample in the small mailing envelope also marked for Nematode samples and the large sample in the large mailing envelope marked for Chemical analysis. ID numbers beginning with 1 are for Nematode samples that will be analyzed in California. Soil sample IDs beginning with 2 are for Chemical samples that will be sent to Lincoln, Nebraska for analysis.

Send one sample per envelope using the pre-addressed, postage-paid envelopes provided. Use strapping tape to close the mailing envelopes. You will be instructed where to drop off the samples for Federal Express pickup. All samples should be mailed on the same day of sampling or first thing the following day. For pickup of Federal Express packages, call l-800-238-5355. The time of the latest pick-up time of a day is available from Federal Express on a 24-hour a day basis by calling the l-800 number and providing the zip code of the pickup address.

IMPORTANT Do not mail nematode samples on Friday. Hold them indoors in the cooler over the weekend, and send them first thing Monday morning.

IV. EXCEPTIONS FOR MULTIPLE SAMPLES:

Some of the fields sampled will have extra soil collected. These fields will be identified in the cover sheet included in your enumerator kit for the field.

Some fields will have samples collected from each of TWO different sampling lines (NASS2, NASS3, HEX5, HEX6). The second closest comer to the original starting comer will be used as the starting comer for pacing to the midpoint of the second sampling line. The number of rows and paces to the midpoint will be different for the second sampling line. The sampling procedure and preparing samples will be the same as described above.

Also, in a small number of fields (NASS3, HEX6). the second sampling line will be used to take twice as many cores. This soil will be split into two equal-volume samples for both “C” and “N” samples. Instead of taking one core at each red stake, take TWO 8”-deep cores for a

total of 40 cores, instead of 20, from the sampling line. Put them all in the same bucket. Mix the double sample thoroughly by hand. From the bucket, remove two beaker fulls of soil, each one to fill an "N" bag. Divide the remaining soil evenly between two "C" bags. Close each bag with a wire tag with the appropriate sample number and mail each bag SEPARATELY in it*s corresponding mailing container (remember only one bag should be placed in each mailing envelope). There will be a total of 3 chemical and 3 nematode bags and their respective mailing containers for these fields. Since there will be no nematodes samples sent from HEX fields, discard the amount of soil you would have used for those samples before packaging them. That way all of the samples going for chemical analysis will be about the same weight.

If you have not already done so, attach labels to the bag tags and record keeping sheet for each bag of soil. The label going on the tag should have nothing but the sample id number,

V. INSTRUCTION SHEETS

Below are examples of the type of instruction sheets that will be included in the enumerator kit to describe the different types of fields to be sampled.

NASS 1

Check to make sure that NASSl appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of the sampling line.

For this field you will mark out:

1 (one) sampling line

Take 20 (twenty) soil cores (1 from each stake).

This line will have both:

1 (one) chemical analysis bag
1 (one) nematode analysis bag

NASS 2

Check to make sure that NASS2 appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of each sampling line.

For this field you will mark out:

2 (two) sampling lines

SAMPLING LINE 1:

Take 20 (twenty) soil cores u from each stake).

This line will have both:

1 (one) chemical analysis bag
1 (one) nematode analysis bag

SAMPLING LINE 2:

Take 20 (twenty) soil cores u from each stake).

This line will have both:

1 (one) chemical analysis bag
1 (one) nematode analysis bag

NASS 3

Check to make sure that NASS3 appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of each sampling line.

For this field you will mark out:

2 (two) sampling lines

SAMPLING LINE 1:

Take 20 (twenty) soil cores (1 from each stake).

This line will have both:

1 (one) chemical analysis bag
1 (one) nematode analysis bag

SAMPLING LINE 2:

Take 40 (forty) soil cores (2 from each stake).

This line will have both:

2 (two) chemical analyses bags 2
(two) nematode analyses bags

HEX 4

Check to make sure that HEX4 appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of the sampling line.

For this field you will mark out:

1 (one) sampling line

Take 20 (twenty) soil cores (1 from each stake).

This line will have:

1 (one) chemical analysis bag

NOTE No nematode analyses will be done on soil from this field. Do not use any bags marked for nematode analysis.

HEX 5

Check to make sure that HEX2 appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of each sampling line.

For this field you will mark out:

2 (two) sampling lines

SAMPLING LINE 1:

Take 20 (twenty) soil cores (1 from each stake).

This line will have:

1 (one) chemical analysis bag

SAMPLING LINE 2:

Take 20 (twenty) soil cores a from each stake).

This line will have:

1 (one) chemical analysis bag

NOTE No nematode analyses will be done on soil from this field. Do not use any bags marked for nematode analysis.

HEX 6

Check to make sure that HEX6 appears on the label for this field. Use the rows and paces marked on the label to locate the midpoint of each sampling line.

For this field you will mark out:

2 (two) sampling lines

SAMPLING LINE 1:

Take 20 (twenty) soil cores (1 from each stake).

This line will have:

1 (one) chemical analysis bag

SAMPLING LINE 2:

Take 20 (forty) soil cores (2 from each stake).

This line will have:

2 (two) chemical analyses bags

NOTE No nematode analyses will be done on soil from this field. Do not use any bags marked for nematode analysis.

Appendix B

Methods Manual for Soil Conservation Service Efforts in the Pilot

APPENDIX 4

METHODS MANUAL for SOIL CONSERVATION SERVICE EFFORTS IN THE PILOT

The following pages contain a description of the methods to be used by soil scientists from the Nebraska SCS office. The methods apply to field characterization and pit sampling on a subset of fields in the 1993 pilot, with the informed consent of the farmer. Also included are copies of the field data sheets that will be used.

Techniques, methods, and procedures for use by field soil scientists were prepared by Norman P. Helzer, State Soil Scientist, Nebraska SCS, and Carol D. Franks, Soil Scientist, National Soil Survey Center, SCS. Modifications by M.J. Munster, EMAP-Agroecosystems, in part to reflect discussions held after the manual was first prepared.

A4.1. Methods Manual

The manual lists the procedures to be used by SCS soul scientists to identify map units and map unit components, to locate the 20 inch deep soil pit, to describe and sample soils, and to assign classes of accelerated erosion.

Procedures to identify map units and map unit components include using remote sensing and soil transect techniques. (Section A4.2)

Nebraska Agricultural Statistics Service (NASS-NE) will provide the aerial photograph used to identify the sample field. It will show the field outline as well as identifying roads or other features needed to locate the field. It will also show the approximate location of the transect. The instructions for pacing 10 the center of the transect will be provided, in case the marking stakes were removed or destroyed. NASS enumerators will drop off the aerial photograph and a copy of the signed consent form (releasing the farmer*s name to SCS) at a county SCS office close to the field. If the field has not been disturbed, but for some reason the stakes marking the transect cannot be located, do not take the sample, as it is likely that you are not at the correct location.

The SCS soil scientist will provide the percent composition, down to the map unit component, of the field in which the EMAP transect is located. These will be sketched on the photograph and recorded on a special data form (included after Section A4.4)

For each EMAP transect, the SCS soil scientist will identify the map unit and map unit component. Lf the EMAP transect crosses a boundary between different soils, the map unit and component(s) at each end of the EMAP transect will be identified. Record this information on the aerial photograph provided by NASS-NE. (Section A4.2)

Locate, describe and sample the soil. On the EMAP transect, locate the soil pit within a pedon (soil individual) that is representative of the map unit/map unit component. If an EMAP transect falls entirely within a single soil dig and sample one 20 inch soil pit. This is to be at the center of the transect. preferably, but can be shifted if the center point is not representative. If an EMAP transect falls across soils with different properties, as determined in the field, pits will be dug on the transect, with one in each component. Pits will be 40 feet from the boundary. thus 80 feet apart, to avoid transition zones between soils. Where an EMAP transect falls in a terraced field, locate and dig the sample in an undisturbed area between the terraces. (Section A4.3)

Describe the soil solum in its entirety. Complete Form SCS-SOI- (232) by hand or by using PEDON software. (Section A4.4) Sample this soil to a depth of 20 inches from a pit within the representative pedon. (Section A4.3) If the EMAP transect

crosses two map units; describe and sample the two soil pits that are 80 feet apart. The minimum kinds of soil and site properties to be described are listed in Section A4.4. Analyses anticipated are particle size analysis. pH. organic carbon, cation exchange capacity and exchangeable cations, total phosphorous, bulk density, 15 bar water retention and calcium carbonate equivalent. Aggregate stability will also be measured as appropriate. Sample at least one horizon and as many as four horizons, insuring that significant horizons in the 0 to 20 inch depth are sampled. Label the samples. Write the EMAP identification on page 5 of the 232 in the "Free Form Site Notes" block. (Section A4.4). Ship soil descriptions, clod samples and soil samples on a weekly basis directly to the SCS National Soil Survey Laboratory at Lincoln, Nebraska. One hard copy of each soil description is to be sent to the Nebraska State Soil Scientist. All samples are to be sent directly to the National Soil Survey Laboratory using preprinted mailing labels provided by the laboratory.

While on site, assign the class of accelerated erosion to each map unit/map unit component in the field. (Section A4.5) Choose one erosion class (or noneroded if applicable) that best describes the field as a whole. Record this information on the supplemental data form. Also, assign an erosion class to each pedon sampled. Record this on page 1 of the 232 in the first block. Do not subdivide a component or a single component map unit into more than one erosion class.

Data taken that is not found on the usual or supplemental forms will need to be reported on page 5 of the 232 in the "Free Form Site Notes" block. For example, the EMAP identification is recorded in this block. Reference the EMAP number that identifies the field.

Samples are received in the Soil Survey Laboratory (SSL) receiving and processing lab. The samples are laid out and given laboratory sample tracking numbers. The 232 is used to identify samples and give them sample numbers for respective pedons and horizons.

Upon completion of analysis a diskette in fixed field ASCII format will be sent to the EMAP-Agroecosystems information manager, Mark Tooley.

These procedures are to be done at a rate of two EMAP fields per day. The quantity and quality of field work is expected to be high and be managed to fit within a 10 hour maxiflex day. The shipping of samples to Lincoln and the entering of the pedon data into PEDON may take additional time the next
day or so. Travel authorization and travel budgeting will be handled by the immediate supervisor of each participating soil scientist.

Several sample sites in fields will be audited by EMAP cooperators. SCS soil scientists are expected to cooperate with EMAP - Agroecosystems Quality Assurance Officers doing Quality Assurance Field Audits.

A4.2. Field Investigation Methods, Landscape and Geomorphic Studies

[(Ref.) National Soils Handbook]

Identifying and delineating major landform units. The soil scientist concentrates on the identifiable components of the delineated landforms, e.g., in hills, the side slope, toe slope, and foot slope components. These kinds of components are delineated consistent with map unit size specifications. Soil patterns commonly coincide with major landforms and individual soils with individual landform components.

Include the interaction between topography, stratigraphy, and hydrology. This helps to separate systematic variability from the random variability in mapping associated soil patterns.

Design map units that represent sets of soil properties repeated on characteristic landform components. Design map units that meet the users needs for soil interpretations and management decisions. The following are checked:

- predictive value of soil-landform features;
- internal properties; and
- slope gradient and shape, vegetation, and position on the landform relative to surrounding soils.

Record maps units in sample field. Identify extent and inclusions.

- Remote sensing techniques. Aerial photos have tonal shades and patterns indicating possible changes in vegetation, drainage, parent materials, etc. [(Ref.) Soil Survey Manual (SSM)] Sampling of units depends on whether the answers or relationships we desire are related in a meaningful way with the features of the soil map units. The actual clues are not necessarily soil properties at all, but are features of identification that we associate with the unseen soil models. Mapping in most surveys involves delineating segments of the landscape, cutting out geographic areas, and putting the boundaries on base maps.

- Some map units designed for specific landforms include

1. Ridge (includes summit and shoulder)
2. Stream terrace

Tonal shades and patterns on aerial photographs are used to indicate possible changes of vegetation, drainage conditions, materials, and so forth. The patterns of the gray tones are used to delineate areas on maps. As we look at the existing vegetation, we see differences that correspond to tones and composition of the species makeup, and we verify or modify the boundary locations of the units accordingly. Configurations of the visible surface of the land, stones. and other features are used as evidence of changes important enough to be recognized as separate areas.

Many schemes have been proposed and tested for determining the composition of map units. The same can be said for the distribution of properties that exist. It is fairly well accepted that certain features of soils and of landscapes are not in accord with existing models of distributions in systematic and predictable ways. Therefore, it is common to employ soil transects to estimate the composition of map units. These should not be confused with the transects being used by NASS enumerators to collect surface soil for this project. The first aspect of composition is to identify the soil taxonomic components because taxonomic class is related to soil genesis and morphology.

- Soil Transects are used to estimate composition and to communicate field observation by taxonomic component (responses or indicators for interpretive purposes). Detailed profile descriptions with soil properties recorded support line separation.

Identify map unit crossed by EMAP transect. Record this information on the supplemental data form. Procedures include the following techniques:

- Identify landforms
- Remote sense patterns on aerial photograph
- Field examination of landform; and position and shape within landform
- Use properties identified in the soil and landform features to draw any needed map boundary line
- If necessary, do a soil transect with soil profile description of solum.

Map Unit Components and Boundaries.

[(Ref.) MLRA (Major Land Resource Area) Handbook (Draft)]

The following describe the evaluation of soil map units and boundaries (tabular and spatial information) through transect methods. Information on soil transect and statistical analysis is included here.

Why do we need soil transect information? When mapping, a soil scientist predicts where soils are likely to change in the landscape and makes observations to test the prediction. The better the landscape model, the more accurate the predictions are about changes in soil types across the landscape.

In soil transecting, observations are made based on a predetermined spacing. A larger number of observations are made in a delineation as compared to mapping. The observations are of the major soil making up the delineation as well as included soils. No sites are ignored as being "unrepresentative."

Determine the composition of map units. This includes an estimate of the amount of named and similar soils and contrasting soils.

At each point in a soil transect, the taxonomic class of the soil is identified. Other kinds of data gathered consist of measurements and observations of soil and site properties. For example, the kinds of data gathered on a steep, stony unit normally will be different from data gathered on a level, frequently flooded, poorly drained unit.

Analysis of Soil Transect Data. Determine taxonomic composition. It also is important to visually inspect your soil transect data and look for patterns or trends.

Existing Soil Map Units. The first step in assessing the quality of existing soil mapping is to evaluate line placement. Specifically, do the lines conform to natural landscape breaks and are alI important natural soil-landform units delineated?

Map Unit Boundaries. For each map unit, determine what information needs to be gathered. Information for other properties such as slope, stone cover, depth to redoximorphic features, surface texture, depth to bedrock, etc. wiII be observed and documented when appropriate. This list will vary for each map unit.

A4.3. The sample

[(Ref.) "Principles and Procedures for Using Soil Survey Laboratory Data"]

Selecting the site. Sites representative of the soil in the survey area are purposefully selected for sampling using the transect site method. In this study, fields and transect sites are preselected.

Sampling the pedon. The sampling party has responsibility to obtain samples representative of the pedons selected for characterization. Decisions are necessary on horizon delineation, thickness of horizon (or interval) sample, what material should be

excluded from the sample, and the usefulness of compositing samples. The sampling party insures that site and pedon descriptions are adequate,

The ideal sample contains all soil materials within the horizon in proportion to their occurrence in the pedon. The sampler attempts to approximate the ideal by carefully sampling a selected section of the horizon. The sample is normally taken along a pit face from horizon boundary to horizon boundary and between arbitrary lateral limits encompassing short range variability observed at the site.

For this study, sample as appropriate for aggregate stability determination. (See reference at end of this Appendix for method of sampling).

Bagged samples

The Label "For want of identification, the sample was lost." Too often this sentiment is expressed. Labeling is critical. Record the identification on page 1 of the SCS-SOI-(232) in the first block. Four elements need to be included to eliminate confusion.

1. Pedon and horizon number.
2. Depth.
3. Horizon designation.
4. Record the EMAP identification on page 5 of the 232 in block "Free Form Site Notes".

The soil name is helpful. Use lead pencil or water-proof ink. Label outside of container.

Tag Example:

Soil Name Sample No. County Horizon Depth (inches)

For plastic bags, staple a tag between folds at the top of the bag--on the outside.

Assignment of Pedon and Horizon Numbers

Pedon is identified on page 1 of the 232 in the first block. Horizon Numbers are recorded on page 2 of the 232.

The unique identifier for any sampling site is the soil survey number assigned at the time of sampling. It is also the number by which the data for that sample may be retrieved from the pedon data record.

Assign soil survey numbers as follows:

1. Begin with S to indicate special sample.
2. Use the last two digits of the calendar year.
3. List the two-letter state FIPS code followed by a hyphen.
4. List the three-digit county FIPS code followed by a hyphen.
5. Within each calendar year, number each pedon chronologically as sampled in that county (state soil scientist keeps this record).

This completes the pedon designation. An additional number can be added to identify the horizon sampled.

6. Horizons are numbered sequentially from the top on page 2 of the 232. Add a hyphen and numeral to indicate the horizon sampled. (NOTE: Sequential horizon numbers remain the same even if all horizons not sampled.)

Samples sent to National Soil Survey Laboratory should be:
representative of horizon
- at least 4 kg in size
- placed in plastic bag
- labeled with tag on outside of bag (this label matches the information on the 232)
- accompanied with pedon description complete with volume estimates of coarse fragments

Bulk density samples. Samples for bulk density are approximately fist-sized clods of undisturbed soil. If clods cannot be secured; i.e., in sands, core samples are taken. Three clods are collected per horizon.

Sampling (Bulk Density Clods)

1. Take three clods per horizon for bulk density.
2. Make clods spherical to egg-shaped, 6 to 7 cm in diameter.
3. Put fragile clods in a hairnet; put firm clods in a double wire loop.
4. Hang clod; coat once quickly with Saran; allow to dry.

Packaging

1. Assemble box so numbers on lid are on inside.
2. Make cells and lid numbers correspond as shown in diagram. (Number four cells in box.)
3. Label lid to identify clods in cells.
4. Put coated clod in a plastic bag and place in cell of clod box. DO NOT REMOVE WIRE OR NET.
5. Use all cells or stuff empty cells with a filler such as newspaper.
6. Secure lid with strapping tape prior to transport. Individual boxes can be shipped.

Additional Information on soil Sampling and Analysis.

[(Ref.) National Soils Handbook]

Samples are collected by soil horizon. Samples are collected for all horizons. Sampling is most beneficially conducted from excavations. Use air-dry bulk samples. Samples need to be large enough to represent the proportion of rock fragments up to 20 mm (3/4 in.) in diameter (determined by weight in the laboratory) and to provide at least one quart of less than 2 mm material. Proportions of rock fragments larger than 20 mm (314 in.) are estimated by volume in the field. The routine method for bulk density and moisture retention determinations require clod samples which preserve the field configuration of pore space. Sampling equipment and supplies are bags, tags, shipping documents.

Sample Collection and Preparation

[(Ref.) Soil Survey Laboratory Methods Manual, Soil Survey Investigation Report #42]

Cardboard boxes are used for shipping natural clod samples for bulk-density studies. Bulk samples are collected in 8-mil plastic bags, 23 x 51 cm (9 x 20 in), that are closed before shipping by stapling the folded opening. The samples are then shipped in canvas laundry bags.

Field Sampling and Site Selection

Site selection, descriptions of the site and soil, and careful sample collection are requisite to successful soil analysis. If a transect is to he sampled, care must be taken to ensure that the variable being tested can be adequately assessed after considerations of other variables in the transect.

Pedon Sampling

Sample freshly dug pits. Dig the pit at least 20 inches deep. Make supplemental borings or excavations if necessary to assess **and** describe pedons larger than the pit. In laterally uniform pedons, sample in a vertical pattern 30 to 50 cm. wide. Each sample should represent the entire cross section of each horizon**.** Place a 3- to S-kg sample, representative of the horizon, in an 8-mil, 4L plastic bag (about three-fourths full). Fold top of bag, place tag in fold and staple. Mark depth, horizon, and pedon number on the tag. Clods for determining bulk density and water retention are normally too small to cover the entire cross section of the horizon and should be taken from the center. Clods can be packaged in plastic bags and placed in cardboard clod boxes for transport. If convenient, start sampling at the bottom of the pit to minimize contamination.

If rock fragments >20 mm are present, follow procedures outlined in Appendix C. For contrasting soil materials, estimate the proportions of each component and record in the pedon description. Sample components separately. if reasonable. Make arbitrary subhorizons if morphologically recognizable horizons are more than 30 cm thick in the upper part of the pedon or more than 60 cm in the lower part. Consider the requirements of the classification system in locating subhorizon boundaries,

If, for some reason, a pit cannot be dug, samples can be taken with a probe core technique. Bulk and clod samples can be taken from probe cores; however, cores smaller than 5 cm are not suitable for bulk density and water content determination.

[(Ref.) Fabric-Related Analyses, Aggregate Stability (4G), Soil Survey Laboratory Methods Manual]

Application. An aggregate is a group of primary particles that cohere to each other more strongly than to other surrounding soil particles (Kemper and Rosenau, 1986). Disintegration of soil mass into aggregates requires the application of a disrupting force. Aggregate stability is a function of whether the cohesive forces between particles can withstand the applied disruptive force. Erodibility of soils increased as. aggregate stability decreases (Kemper and Rosenau, 1986). The datum can serve as a predictor of soil*erosion potential.

[(Ref.) Aggregate Size Distribution. Overview of Certain Soil Characterization Methods With Emphasis on Use Dependant Temporal Properties, R.B. Grossman]

Aggregate Size Distribution. For the EMAP sample, collect or sample loose soil without sieving in the field. Method G001

Sample Loose Soil Without Sieving in the Field. Method G00l. The determination is made on relatively loose near-surface soil which is air dried and passed through a nest of sieves in the NSSL in Lincoln.

A4.4. Examination and Description of Soils

[(Ref.) Soil Survey Manual]

For rapid investigations of soils, a small pit can be dug and a section of soil removed with a spade. Knowledge of the internal properties of a soil is derived mainly from studies of such samples. Complete study of an entire pedon requires the exposure of a VERTICAL section and the removal of horizontal sections layer by layer. Horizons are studied in both horizontal and vertical dimensions.

The description of a body of soil should record kinds of layers, their depth and thickness, and the properties of each layer. A pedon represents the desired segment of its range.

Pedons representative of an extensive mappable area are generally more useful than pedons that represent the border of an area or a small inclusion. For a soil description, the vegetation and part of the landscape that the pedon represents should be described.

A pit exposing a vertical face approximately 20 inches is satisfactory for this project. Sides of the pit are cleaned of all loose material disturbed by digging, the exposed vertical faces are examined, usually starting at the top and working downward, to identify significant changes in properties. Boundaries between layers are marked on the face of the pit, and the layers are identified and described.

Patterns of color within structural units, variations of particle size from the outside to the inside of structural units, and the pattern in which roots penetrate structural units are often seen more clearly in a horizontal section. The depth to a horizon or layer boundary commonly differs within short distances, even within a pedon.

For this study:

- Sample soil pit 20 inches deep.
- Describe soil profile to 60 inches in order to classify the whole soil profile. To do this, expose the entire profile or auger/probe sample from the entire 60 inch depth.
- Collect bulk soil sample by horizon (bottom to top)
- Package soil sample in plastic bags with identification labels.
- Collect bulk density clod samples; dip in saran and box.

Additional guidance for sample collection and preparation is in Appendix B.

Soils with rock fragments

[(Ref.) Soil Taxonomy]

Soil Texture, Coarse Fragments, Stoniness, and Rockiness. Soil Texture refers to the relative proportions of the various size groups of individual soil grams in a mass of soil. Specifically, it refers to the proportions of clay, silt, and sand below 2 millimeters in diameter. The presence of coarse particles larger than very coarse sand (or 2 millimeters) and smaller than 10 inches is recognized by modifiers of textural class names, like gravelly sandy loam or cobbly loam. General classes of still larger particles - stones or rock outcrops are defined in terms of the influence they have on soil use, and in specific physical terms for individual soil series.

[(Ref.) Soil Survey Manual]

Size limits. The upper size limit for rock fragments is the size of the pedon. The term "rock fragments" refers to particles 2 mm in diameter or larger and includes all sizes that have horizontal dimensions less than the size of a pedon. It is not the same as coarse fragments, which excludes stones and boulders larger than 250 mm. Coarse fragments are 2 to 250 mm. Laboratory data sheets normally report size classes up to 75 mm or 250 mm. The largest size sent to the laboratory with 3 to 5 kg samples is
20 mm.

Volume estimates. Record in the pedon description. the volume percentage estimates of rock fragments >250 mm (10 in), 75 to 250 mm (3 to 10 in), and 20 to 75 mm (3/4 to 3 in). Collect a 3 to 5 kg sample of the <20-mm soil material, and store it in a plastic bag. Calculate the volume percentages of coarse fragments;

*Weight **estimates.*** Estimate and record the volume percentage of the >75 mm fraction as outlined in volume estimates. Collect and weigh a 15 to 20 kg sample of the <75 mm fraction. Record the weights of the 20 to 75 mm fraction and the <75 mm fraction. Collect a 3 to 5 kg sample from the <20 mm fraction, and store it in a plastic bag. Calculate the weight percentage of coarse fragments.

Minimum kinds of soil site properties to be described:

1. Soil classification
2. Major Land Resource Area
3. Latitude and longitude
4. Land use, crop or native vegetation
5. Slope (8)
6. Landform
7. Micro relief
8. Aspect
9. Accelerated erosion class
10. Permeability (hydraulic conductivity class)
11. Drainage class
12. Elevation
13. Water table (when applicable)
14. Moisture
15. Roots
16. Rock fragments (8) by volume
17. Miscellaneous land type (8)
18. Parent material
19. Hydrologic group (free form notes)
20. Salt (electrical conductivity) when present (free form notes)
21. Texture (particle size)

22. Clay %, (free form notes)
23. Sand 8 (free form notes)
24. Horizons
25. Depth (in.)
26. Color (moist/dry)
27. Consistency (Rupture resistance)
28. Mottles (Redoximorphic features
29. Pores
30. Chemical reaction
    a. Ph
    b. effervescence class (HCL)
31. Concentrations
32. Structure
33. Crusted (yes/no) (free form notes)
34. Collect Bulk Density clods (free form notes)

Field Worksheet NE-Land Use 10-15-93

Segment #_____ SS Name_____

Tract #_____ Date_____

Field #_____ County_____

First Map Unit

Symbol_____ Name_____

% of Field_____ Erosion Class of Map Unit_____

Component(s)	Taxon	% of Map Unit	Erosion Class
First			
Second			
Third			
etc.			

Second Map Unit:

Symbol_____ Name_____

% of Field_____ Erosion Class of Map Unit_____

Component(s)	Taxon	% of Map Unit	Erosion Class
First			
Second			
Third			
etc.			

Third Map Unit:

Symbol_____ Name_____

% of Field_____ Erosion Class of Map Unit_____

Component(s)	Taxon	% of Map Unit	Erosion Class
First			
Second			
Third			
etc.			

UOM _
Series: _____
Date: __/__/__
State: __
SSA: ___
Unit: ___
Subunit: _
MLRA: ____
MU Symbol: _____
Description Type: __
Pedon Type: ___
Component Kind: _
Comp. Name: _____
SSA Name: _____
Map Unit: _____

Classification
O: _ PSC: ___
SO: __ Min: ___
GG: __ Rx: ___
SG: ____ Tmp: ___
Other: ___

Lab Samp #: _____
Lab ID: _____
Note ID: _____
Yld. ID: _____
Photo #: _____
Land Use: _
Stoniness (%): __.__
Permeability: _
Drainage: __
Elevation: _____
Maj Lndfm: ___
Loc Lndfm: ___
Mst Rge.: ___
Ctl. Sec. Up: ___._
Ctl. Sec. Low: ___._

Micro Relief
Kind: _
Size: ___
Pattern: _
Pedon Pos: __

Slope
Percent: ___
Aspect: ___
Up Shape: __
Across Shape: __
Geomorphic: __
Hillslope: __
Len. Abv.: _____
Len. Tot.: _____

Erosion
Knd: _ Deg: _
Runoff: __

Windows
Location: X
Parent Material: X
Diagnostic: X
Describers: X
Transect: X
Other: X

Associated Soils:
and Misc. Land Types

User Defined Properties

Code	Value

Diagnostic Features

Depth Upper	Depth Lower	Feature Kind
___._	___._	___
___._	___._	___
___._	___._	___
___._	___._	___
___._	___._	___

Transect Data

Transect ID _____
Interval ____
Stop Number __

Latitude
Deg: __
Min: __
Sec: __._
Dir: _

Longitude
Deg: ___
Min: __
Sec: __._
Dir: _

UTM Zone: __
Easting: _____._
Northing: _____._
County FIPS: ___

County Name: _____
Quad: _____
Location:
_____
_____
_____

Parent Material

Dep	Knd	Weath	Dip	Strk
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___
_	___	___	___	___

Bedrock Information

Kind: ___ Fracture: _
Dip: ___ Hardness: _
Strike: ___ Weathering: __

Author Information

Author(s): _____
_____
_____

Precip: ____

Air Temp
Ann: __
Sum: __
Win: __

Soil Temp
Ann: __
Sum: __
Win: __

Climate Station
ID: _____
Type: _____
Name: _____

Temporal Data

Flooding	Ponding	Water Table
Freq: __	Freq: __	Depth: ___
Mo: ___	Mo: ___	Kind: _
Days: ___._	Days: ___._	Days: ___

U.S.D.A.
S.C.S.
SOIL DESCRIPTION
DRAFT
SCS-SOI-232
12-92

p:

DEPTH upp	DEPTH low	HORIZON Number & Name	THICKNESS min	THICKNESS max	THICKNESS avg	MATRIX COLOR msot	MATRIX COLOR loc	MATRIX COLOR t	MATRIX COLOR hue	MATRIX COLOR val	MATRIX COLOR chr	TEXTURE cls	TEXTURE mod	STRUCTURE grd	STRUCTURE sz	STRUCTURE shp	STRUCTURE prt	RUPTURE RESISTANCE dry	RUPTURE RESISTANCE mst	RUPTURE RESISTANCE rup cem	RUPTURE RESISTANCE agl	RUPTURE RESISTANCE fal	RUPTURE RESISTANCE stk	RUPTURE RESISTANCE sls	RUPTURE RESISTANCE plp	RUPTURE RESISTANCE rpl	RUPTURE RESISTANCE ulpt	RUPTURE RESISTANCE tgh
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DEPTH		HORIZON	THICKNESS			MATRIX COLOR						TEXTURE		STRUCTURE				RUPTURE RESISTANCE							
upp	low	Number & Name	min	max	avg	mst	loc	%	hue	val	chr	cls	mod	grd	sz	shp	prt	dry	mst	rup	cem	agl	fal	stk	slp	rpt	ult	tgh
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FORM SCS-SOI-232 PAGE 4

DEPTH		HORIZON	CONCENTRATIONS										ROCK FRAG				FEATURE			MISCELANEOUS INFORMATION						USER DEFINED PROPS		BND	
upp	low	Number & Name	knd	%	shp	sz	loc	hue	val	chr	hrd	org	knd	vol	rnd	sz	knd	lat	tot	wat con	wet	pnt	per	1:1 H2O pH	lab sample number	cd	val	dst	tpo
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Vegetation Information

Common Name:
Crop

Symbol:

Association:

Free Form Site Notes:

Collect Bulk Density Clods
Hydrologic Group
Crusted (yes or no)
EMAP identification:

Formatted Horizon Notes:

Free Form Horizon Notes:

Salt (Electrical Conductivity)
Clay %
Sand %

A45 Erosion (by component)

The following classes of erosion will be the standard or reference by which surface layers are judged. Erosion is often variable, but for this study, the classes of "noneroded" and "slight" will be combined with normal or uneroded soil. The classes "moderate" and "severe" will be combined to form the eroded soil category.

[(Ref.) Soil Survey Manual]

Classes of Accelerated Erosion

The classes of accelerated erosion that follow apply to both water and wind erosion. They are not applicable to landslip or tunnel erosion. The classes pertain to the proportion of upper horizons that have been removed. These horizons may range widely in thickness; therefore, the absolute amount of erosion is not specified.

Noneroded

A noneroded soil has no loss.

Slight

This class consists of soils that have lost some, but on the average more than 0 but less than 25 percent, of the original A and/or E horizons or of the uppermost 20 cm if the original **A** and/or E horizons were less than 20 cm thick. Throughout most of the area, the thickness of the surface layer is within the normal range of variability of the uneroded soil. Scattered small areas amounting to less than 20 percent of the area may be modified appreciably.

Evidence for slight erosion includes (1) a few rills (2) an accumulation of sediment at the base of slopes or in depressions, (3) scattered small areas where the plow layer contains material from below, and (4) evidence of the formation of widely spaced, deep rills or shallow gullies without consistently measurable reduction in thickness or other change in properties between the rills or gullies.

Moderate

This class consists of soils that have lost, on the average, 25 to 75 percent of the original A and/or E horizons or of the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. Throughout most cultivated areas of moderate erosion, the surface layer consists of a mixture of the original A and/or E horizons and material from below. Some areas may have intricate patterns, ranging from uneroded

small areas to severely eroded small areas. Where the original A and/or E horizons were very thick, little or no mixing of underlying material may have taken place.

Severe

This class consists of soils that have lost, on the average, 75 percent or more of the original A and/or E horizons or of the uppermost 20 cm if the original A and/or E horizons were less than 20 cm thick. In most areas of severe erosion, material below the original A and/or E horizons is exposed at the surface in cultivated areas; the plow layer consists entirely or largely of this material. Even where the original A and/or E horizons were very thick, at least some mixing with underlying material generally took place. In some small areas, the original soil can be identified only with difficulty. Some areas may have an intricate pattern of gullies.

Appendix C

SOP for the Modified Cobb's Sifting and Gravity Method*

EXTRACTION PROCEDURE

A. Modified Cobb's Sifting and Gravity Method.
(Ayoub, 1980; Thorne, 1961; Noffsinger, Personal Experience)

1. Soil Sieve Sizes (8 inch dia., 2 inch depth)
   a) No. 25 sieve (710 µm)
   b) No. 60 sieve (250 µm)
   c) No. 100 sieve (150 µm)
   d) No. 200 sieve (75 µm)
   e) No. 325 sieve (45 µm)
   f) No. 400 sieve (38 µm)

2. Stainless Steel Bowls
   a) 2 @ l-gallon
   b) 1 @ l/a-gallon
   Note: to run multiple samples, buy extra l/2-gallon bowls. These are the pans used to soak the soil samples.

3. Other Equipment
   2 wash bottles, sugar, 600 ml beakers, rubber spatula, bucket, small diameter (l/8" I.D.) flexible (Tygon) tubing for siphoning, disposable latex gloves, apron or lab coat that is waterproof, tape for labeling sample extract, pen or marker, large powder funnel and stand with clamp.

4. Presoak Sample- (at least 15 min.)
   Pour 500 ml soil sample into a l/2 gallon bowl, then add tap water until sample is covered by 3/4" to 1' of water. Gently work the soaking sample so that all the clay clumps break apart (usually takes between 7 to 15 minutes depending on the soil type).

5. Stir soaked sample (with hand or spatula) and pour liquid portion through the #25 sieve into large (1 gallon) bowl 'A'.Backwash sieve into a beaker(labeled with sample name or number, and "Part A"). You should/will have a thick slurry of soil in the bottom of the soaking pan. Rewet this soil residue in the l/a-gallon bowl (that which was not poured through) so that l/4" to l/2" of water covers it, and stir and pour through the #25 sieve again. Backwash sieve into beaker "Part A". Repeat the process one more time.Discard the remaining soil in the l/2 gallon bowl.

6. Stir and quickly pour solute in large bowl 'A" through #60 sieve into large bowl "B". Backwash sieve into beaker "Part A" used in step 5. Once

again, there will probably be a thick slurry of soil left in the bowl you just poured from, a l b e i t a fairly small amount. My method of dealing with this residue is to splash water in it (probably less than 50 ml), swirl it around for a couple of seconds, and then pour most of it directly into the bowl containing the solute (in this case bowl "B"). then rinse out the bowl (in this case bowl "A") that you just poured from. This portion of the procedure will probably have to be repeated every time you pour through a sieve, for all sieve sizes. Stir and quickly pour solute in bowl 'B" through sieve into bowl "A". Backwash sieve into beaker 'Part A" used in step 5. Stir and quickly pour bowl "A" through sieve into bowl "B".
Backwash sieve into beaker "Part A" used in step 5. Beaker "Part A" should be set aside to settle for 4 to 5 hours.

7. Repeat step 6 using the #l00 sieve, and a new beaker (Part B") to hold the backwashings. Repeat again using the #200 and #325 sieves, using the same beaker (Part "B") as used for the #l00 sieve for the backwashings. Most times I need a third beaker (sometimes a fourth) to hold all the extract. If I need an extra one for the procedure in part 5 then I would label it the same as the beaker used in part 5 ('Part A"), as the two will be combined after the first siphoning. Conversely, if I need an extra beaker for the procedure in part 6, then the additional beaker would be labeled "Part B', and combined with the other "Part B" beaker after the first siphoning.

8. Allow all beakers labeled 'Part A" and "Part B" to settle for 4 to 5 hours, in a refrigerator if feasible, then carefully siphon off excess water. Usually the "Part A' beaker has 50 to 75 ml of soil in the bottom, while the "Part B" beaker often has 75 to 150 ml of soil in the bottom. My method of siphoning is to start with the tube end near the surface of the water, and work it down as the water level falls. When the end of the tube gets to within l00-125 ml of the soil surface (l/2" to 3/4") don't move it any futher down, but gently tilt the beaker toward the tube. While tilting the beaker, watch from above the soil and water interface. As the top layer of soil begins to move with the water, remove the tube from the beaker. This method should get the water level down to 75-100 ml above the soil. Repeat for all the beakers. If multiple "Part A" or "Part B" beakers were needed for a given sample they should be combined after siphoning ("Part A" with "Part

A","Part B" with "Part B") .You are now ready for the sugar centrifugal-flotation method.

GENERAL NOTES

1. Wet sieves before using in the procedure, as the smaller meshes especially can be hydrophobic when dry.

2. Always hold sieve at an angle (approximately 30-40 degrees) while pouring through it.This decreases the chance of nematodes falling directly through mesh openings.

3. Tapping the edge of the sieve while pouring through it facilitates solute movement through the screen. This can be very difficult to do, and takes practice. You need to try to rotate your wrist back and forth, striking the edge of the sieve against a hard object so that the contents are jarred, but not spilled, and all this is done over the bowl. Creativity is encouraged here, and is necessary. If the sieve is very full when you are done pouring through it, you can tap the edge of the sieve with a heavy rod (I use the handle end of a scrub brush that is about 18' long).

4. An alternative to backwashing the sieves with a washbottle is to hook a hose up to your faucet that has a fogger attachment on the end of it. An attachment can be purchased from a nursery supply catalog or store. One must use care, though, and not use too much pressure. Too much pressure can blow nematodes of the screen away from the funnel, and can contribute to excess water accumulation.

5. I've found that using a large powder funnel(powder funnels have parallel stems) with a 150 mm mouth (approx. 1, clamped to a stand, is very useful. The sieve can rest on it without other support, and with the wide mouth, there is less chance of losing any backwashing. Be sure to rinse funnel into beaker, and clean it between samples.

6. A rule of thumb on settling times: Nematodes settle at a rate of 1 inch per hour. So if you have a beaker with 4 inches of water in it, let it settle at least 4 hours before siphoning.

7. Clean all equipment, including the sieves, between runs with warm or hot water, but no detergents.

8. I have suggested 600 ml beakers for this method because 1) I have a lot of them at hand, and 2) they work well for me. Any size will do, but I would point out

that if smaller beakers are used, there will be a lot more of them to keep up with per sample. With the amount of extract I am getting per sample, a 600 ml beaker is the minimum size I would suggest. Results may vary per individual.

9. The 400 µm sieve is used in the sugar centrifuge flotation method.

Appendix D

SOP for the Modified Sugar Centrifugal-Flotation Method

B. Modified Sugar Centrifugal-Flotation Method. (Caveness & Jensen, 1955; Pers. Comm., T Burlando, Dept. Nematol., UCD and Noffsinger, Pers. Exper.)

1. Make a sugar solution (1 part water : 1 part sugar vol:vol. Pour some into a washbottle.

2. Add one part sugar solution to one part contents 'Part A" beaker from the modified Cobb sieving method (total volume often approximately 200 ml), and the "Part B" beaker (approximately 400+ ml. final vol.).

3. Stir and pour beaker contents into centrifuge tubes, making sure that all the material gets into the tubes by backwashing the beaker with the sugar solution waterbottle, and a waterbottle with water (tap is fine). Each tube should have an equal amount of liquid in it. To make up small differences use water or sugar solution. To make up large differences use sugar solution. The point being that the sugar solution to extract solution ratio is at least and as close to 1:l (v:v) as possible, and a higher ratio (eg. 1.25:1)is better than a lower one.

4. Centrifuge for about 1 minute (start to finish - brake not used). The centrifuge we use is large, and I put the tubes in, close it up, turn it on by turning the speed dial to 20,000 rpm, let it spin approximately 40-45 seconds, then turn the speed dial to 0(zero). Within 20 to 30 seconds the centrifuge will have stopped.

5. Decant the upper clear solution from the tubes with 'Part A' extract through a #400 sieve. Rinse sugar off of nematodes by carefully submersing sieve in tub of running water. Sieve should be held at an angle, and care should be taken so that nematodes do not float out of sieve, or are held underwater long enough for them to swim through mesh. I generally dunk the sieve 3 to 4 times, carefully swirling it to move the soil particles and (hopefully) the nematodes around.

6. Backwash sieve into a new 600 ml beaker, making sure that it is labeled appropriately.

7. Repeat above steps for the tubes with "Part B", backwashing sieve into same beaker used in step 6.

8. Fill the beaker up with tap water and allow to

settle for 4-5 hours (in refrigerator if possible) then siphon/pipette and repeat. This step is necessary to completely wash sugar off the nematodes.

GENERAL NOTES

1. Samples should last a week in the refrigerator.

2. In part 8, siphon the bulk of the water off (too 400 ml) then carefully pipette the liquid level down to" approximately 75 to 100 ml.