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# Agroecosystem

# 1992 Pilot Project Plan

## Environmental Monitoring and Assessment Program

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**Environmental Monitoring and Assessment Program**

# *Agroecosystem 1992 Pilot Project Plan*
(April 3, 1992)

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# Glossary of Acronyms

| | | |
|---|---|---|
| AIC | - | Agroecosystem Information Center |
| APHIS | - | Animal and Plant Health Inspection Service |
| ARG | - | Agroecosystem Resource Group |
| ARS | - | Agricultural Research Service (USDA) |
| ASCS | - | Agricultural Stabilization and Conservation Service |
| ASTM | - | American Society for Testing and Materials |
| AVHRR | - | Advanced Very High Resolution Radiometer |
| AWC | - | Available water capacity |
| BRG | - | Business Resources Group, Inc. |
| C | - | Carbon |
| CEC | - | Cation exchange capacity; Commission for European Communities |
| CGIA | - | Center for Geographic Information and Analysis |
| CRP | - | Conservation Reserve Program |
| DAT | - | Digital audio tape |
| DBAPE | - | Database Analyzer and Parameter Estimator |
| DC | - | District of Columbia |
| DLG | - | Digital line graph |
| DQO | - | Data quality objective |
| EC | - | Electrical conductivity |
| ECD | - | Electron capture detector |
| EIC | - | EMAP Information Center |
| ELISA | - | Enzyme-linked immunosorbent assay |
| EMAP | - | Environmental Monitoring and Assessment Program |
| EPA | - | Environmental Protection Agency |
| ERL | - | Environmental Research Laboratory |
| ERS | - | Economic Research Service (USDA) |
| ESP | - | Exchangeable sodium percentage |
| FPD | - | Flame photometric detector |
| GI | - | Greenness index |
| GIS | - | Geographic information system |
| Hall ECD | - | Hall electrolytic conductivity detector |
| HI | - | Harvest index |
| HQ | - | Headquarters |
| HT | - | Horvitz-Thompson |
| ID | - | Identification/identifier |
| IM | - | Information management |
| IMC | - | Information Management Committee |
| INEL | - | Idaho National Engineering Laboratory |
| JES | - | June Enumerative Survey |
| LAI | - | Leaf area index |
| LAN | - | Local area network |
| LCG | - | Landscape Characterization Group |
| LPT | - | Landscape pattern type |
| MLRA | - | Major Land Resource Area |
| NAPP | - | National Aerial Photography Program |
| NASDA | - | National Association of State Departments of Agriculture |
| NASS | - | National Agricultural Statistics Service (USDA) |
| NAWQA | - | National Water-Quality Assessment |
| NC | - | North Carolina; North Central |
| NC-R | - | $O_3$-resistant clone of white clover |
| NC-S | - | $O_3$-sensitive clone of white clover |

Glossary of Acronyms cont'd.

| | | |
|---|---|---|
| NCCGIA | - | North Carolina Center for Geographic Information and Analysis |
| NCDA | - | North Carolina Department of Agriculture |
| NCSU | - | North Carolina State University |
| NDVI | - | Normalized Difference Vegetation Index |
| NE | - | Northeast |
| NGO | - | Non-governmental organization |
| NOAA | - | National Oceanic and Atmospheric Administration |
| NPD | - | Nitrogen-phosphorus detector |
| NPP | - | Net primary productivity |
| NRI | - | National Resources Inventory (USDA/SCS) |
| $O_3$ | - | Ozone |
| OM | - | Organic matter |
| OMB | - | Office of Management and Budget |
| ORD | - | Office of Research and Development (EPA) |
| PAR | - | Photosynthetically active radiation |
| PCR | - | Post column reaction |
| PSU | - | Primary Sampling Unit |
| QA | - | Quality assurance |
| QA/QC | - | Quality assurance/quality control |
| RDBMS | - | Relational database management system |
| RUSTIC | - | Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations |
| SAR | - | Sodium absorption ratio |
| SAS | - | Statistical Analysis System |
| SCS | - | Soil Conservation Service (USDA) |
| SE | - | Southeast |
| SI | - | Systeme International (version of the metric system) |
| SO | - | South |
| SOP | - | Standard operating procedure |
| SSSD | - | State Soil Survey Database |
| T | - | Soil erosion tolerance factor |
| TD | - | Technical Director |
| TM | - | Thematic Mapper |
| USDA | - | United States Department of Agriculture |
| USDC | - | United States Department of Commerce |
| USGS | - | United States Geological Survey (USDC) |
| USLE | - | Universal Soil Loss Equation |
| UV | - | Ultraviolet |
| WE | - | West |
| WRI | - | World Resources Institute |

# Acknowledgements

The members of the Agroecosystem Resource Group have interacted with many people during the development of this Plan. Dozens of people have shared information and expertise during various Agroecosystem workshops. Many more have responded to our written inquiries and telephone calls. The level of interest and cooperation from other government agencies, universities and conservation organizations is appreciated. We would like to express our gratitude to all who have contributed to our effort.

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# 1. Introduction

In 1992 a Pilot Project will be conducted in North Carolina by members of the Environmental Monitoring and Assessment Program's (EMAP) Agroecosystem Resource Group (ARG). The EMAP is an Environmental Protection Agency (EPA) initiative in which the U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS) was asked to give technical leadership to the Agroecosystem component. Thus the Technical Director (TD) of the ARG is with the USDA-ARS. ARS asked the USDA's National Agricultural Statistics Service (NASS) to cooperate in the development and data collection aspects of the Pilot project. These three agencies are the principal cooperators in the Pilot, which is an important developmental step towards the implementation of a plan for monitoring the ecological condition of agroecosystems in the United States. This document is an implementation plan for the Pilot project and represents the combined effort of the members of the ARG (Appendix 1). Every attempt has been made to include pertinent information in this document; however, as plans continue to develop and methods become refined, changes will necessarily be made.

## 1.1. Overview of The Agroecosystem Program

This section is intended to provide a brief overview of the Agroecosystem component of the EMAP Program. For a more detailed description of the Program, the *Environmental Monitoring and Assessment Program (EMAP) - Agroecosystem Monitoring and Research Strategy* (Heck et al. 1991) should be consulted.

### *1.1.1. Establishment and Purpose*

The agroecosystem monitoring program, as one component of EMAP, is a national program administered by the EPA's Office of Research and Development (ORD) in cooperation with several USDA agencies (Heck et al. 1991). In the past decade, environmental scientists have identified the need for more relevant and accessible ecological data, and the EPA has been

encouraged to adopt an ecological perspective of the environment, in which the ecosystem is the fundamental unit of research and monitoring. In 1988, EPA, in cooperation with other agencies and organizations, initiated EMAP to provide baseline estimates of the condition of U.S. ecological resources and follow changes and trends that could be computed with statistical confidence (Kutz and Linthurst 1990).

The Agroecosystem Resource is one of seven resource categories within EMAP. The Agroecosystem Resource Group (ARG) was established in 1988 to initiate the development and implementation of a monitoring and assessment program to determine the status and extent of U.S. agroecosystems. Roy E. Cameron (Lockheed Engineering and Science Co.) served initially as Acting Technical Director. In 1989, Walter W. Heck [U.S. Department of Agriculture, Agricultural Research Service (USDA, ARS)] was named Technical Director. He has worked with C. Lee Campbell [Department of Plant Pathology, North Carolina State University (NCSU)], the Associate Director, in the development of an interagency, interdisciplinary group of federal, state and private scientists (Appendix 1) which comprise the ARG. Members of the ARG developed an initial Research Plan (Heck et al. 1989) which served as the basis for the current Research Strategy Plan [*Agroecosystem Monitoring and Research Strategy* (Heck et al. 1991)].

### *1.1.2. Mission, Objectives, Definition, and Societal Values*

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). The developmental stages of this national program include this 1992 Pilot Project and subsequent regional pilot and demonstration projects (see Section 10: Resources and Implementation). The pilot and demonstration projects allow for the orderly attainment of full national implementation while assuring essential scientific rigor.

The specific objectives of the agroecosystem program parallel the overall EMAP program objectives, focusing on agroecological resources. When fully implemented the program will meet the following objectives:

- Estimate the distribution of agroecosystems and the status and trends in indicators of ecological condition on a regional basis with known statistical confidence.

- Monitor indicators of pollutant exposure and habitat quality and seek associations between anthropogenic stresses and ecological condition.

- Provide periodic statistical summaries and interpretive reports on ecological condition to the public, to the scientific community, and to policy-makers.

For EMAP, agroecosystems are defined as land used for crops, pastures and livestock; the adjacent uncultivated land that supports other vegetation (hedgerows, woodlots, etc.) and wildlife; and the associated atmosphere, underlying soils, groundwater, and drainage networks (first and second order streams, ponds, and irrigation drainage networks). This definition of agroecosystems recognizes their complexity and emphasizes a holistic approach that considers all components of agroecosystem landscapes.

The ARG also recognizes that certain societal values or concerns are associated with agroecosystems. Three societal values are currently identified as highly relevant to agroecosystems:

- Supply of agricultural commodities
- Quality of natural resources
- Conservation of biological resources

These values and concerns parallel those stated in the 1991 Research Strategy Plan (Heck et al. 1991) and have served as a focus for development of the overall strategy for agroecosystem

monitoring, for the establishment of assessment endpoints, and for the selection of specific indicators (measurements) of ecological condition of the resource. Although not specifically mentioned, socioeconomic factors are recognized as being inherent in these societal concerns.

### *1.1.3. Relationship to Other EMAP Resource Groups and Cross-cutting Activities*

EMAP comprises seven ecosystem resource groups, four integration groups and four coordination groups (Table 1-1). Interdisciplinary and interagency groups of scientists in the seven resource groups are responsible for the collection, analysis, and integration of data from their ecological resource. The four integration and four coordination groups have been established to assist the resource groups and to ensure uniform quality management, consistency, and integration across the program.

Presently, the resource groups are in various stages of development with regard to plans for and implementation of actual monitoring activities (Table 1-2). For example, the Estuaries Resource Group will complete a third season of monitoring in 1992, with activities in the Virginian and Louisianan provinces. The Forest Resource Group will continue monitoring in the New England regions and continue pilots in the Southeastern and Western regions in 1992. The intent, however, is that all resource groups will be ready to implement a national monitoring program by 1997.

The ARG is in continued communication with other resource groups, particularly the terrestrial groups, concerning cross-cutting activities such as indicators, landscape characterization, design, statistics, logistics, QA/QC, and other areas. Discussions of joint efforts in pilot projects have been discussed with all resource groups except Great Lakes and Estuaries. Also, as pilot plans develop, interactions with all of the coordination and integration groups will intensify to insure that the ARG program is consistent and compatible with other activities within EMAP.

Table 1-1. Resource, integration and coordination groups of EMAP.

| Resource Groups | Integration Groups |
|---|---|
| Agroecosystems | Air & Deposition |
| Arid Lands | Integration and Assessment |
| Estuaries | Landscape Characterization |
| Forests | Statistics and Design |
| Great Lakes | |
| Surface Waters | Coordination Groups |
| Wetlands | |
| | Indicators |
| | Information Management |
| | Logistics |
| | Quality Assurance |

Table 1-2. Monitoring activities of EMAP Resource Groups in 1992.

| Resource Group | Activity | Location |
|---|---|---|
| Agroecosystem | Pilot Project | North Carolina |
| Arid Lands | Pilot Project | Colorado |
| Estuaries | Pilot/Demonstration | Virginian/Louisianian Provinces |
| Forests | Pilot/Demonstration | NE, SE, Western Region |
| Great Lakes | Pilot Project | Great Lakes |
| Surface Waters | Pilot/Demonstration | NE |
| Wetlands | Pilot Project | Gulf Coast |

## 1.2. Cooperative Interaction with The National Agricultural Statistics Service (NASS)

The ARG maintains extensive, cooperative interactions with personnel of USDA/NASS, both at the operational and administrative levels. Two members of the USDA/NASS staff serve as regular members of the ARG and as liaison between NASS and the Agroecosystem Technical Director (Appendix 1).

The association with NASS is an integral component of the Agroecosystem program. The Agroecosystem Program will utilize NASS's established and well-accepted, national sampling frame as well as NASS's long experience in performing site visits and interviews with farmers. Over the past 30 years, NASS has developed a network of enumerators and administrators experienced in conducting successful national surveys and monitoring activities. This nation-wide force of trained enumerators, with its proven administrative organization, will be utilized for much of the field assessment in the Agroecosystem Program (see following Sections). It is important to the Program that growers throughout the U.S. are familiar with and have confidence in NASS personnel. The NASS also has an established, well-respected program for tracking, processing and summarizing data acquired in the field (see Section 9). The ARG is thus developing the Agroecosystem Program to make maximum use of these aspects of NASS.

The NASS requirement of data confidentiality is established by law and is well accepted in the agricultural community. This confidentiality requirement (Section 8.3) is essential to the success of the ARG in working with growers in the U.S.

## 1.3. Cooperative Interactions with Other National Programs and Agencies

Discussions are currently in progress with three federal agencies/departments to explore possible cooperative activities with the 1992 Agroecosystem Pilot: USDA, Economic Research Service (USDA/ERS); U.S. Geological Survey (USGS); and the USDA, Soil Conservation Service (USDA/SCS).

The ERS initiated the USDA Area Study Program in 1991 in four study areas across the U.S. They have identified another four study areas for 1992; one area is the Albemarle-Pamlico drainage area of North Carolina and Virginia. The study areas used by the USDA Area Study Program are sampled only once to aid in the development of economic models. In each study area, ERS samples approximately 1000 sites utilizing the SCS National Resources Inventory (NRI) area frame to identify NASS sampling units; NASS enumerators then collect the data. Because of the intense sampling in these study areas and the similarity of ARG and Area Study data elements, we are interested in determining if Area Study Program data can be used to improve or enrich the data collected for the 1992 Pilot of the Agroecosystem Program. Also, ERS is interested in determining if the Agroecosystem Program data, from our continued monitoring, may be of benefit to ERS.

The USGS will implement the National Water-Quality Assessment (NAWQA) Program in the 1990s. The ARG has had several discussions with USGS personnel in the North Carolina office who will be responsible for the development and implementation of the NAWQA program in North Carolina. The NAWQA program will monitor not only water quality within designated watersheds, but also biological indicators of interest to the ARG including habitat quality for wildlife. The NC office is responsible for monitoring the Albemarle-Pamlico watershed and plans to initiate monitoring in 1993.

The SCS conducts the National Resources Inventory (NRI) every five years (from 1982). The ARG and SCS personnel are exploring ways in which NRI data could be integrated with, or supplement information from the Agroecosystem Program. Also, the ARG is exploring the possibility of obtaining specific soils data from SCS for the 1992 Pilot Program.

### 1.4. Projected Implementation Schedule for a National Agroecosystem Monitoring Program

The ARG has developed a multiyear program to establish the national implementation of a suite of indicators by 1997. These indicators will address the assessments endpoints (Section 4)

and identified societal values associated with agroecosystems. The first stage of the program (1990) encompassed the initial evaluation of: 1) statistical designs, 2) existing monitoring programs (i.e., NASS, SCS, ERS), 3) assessment endpoints and associated indicators (for their availability, validity, variability, cost) (Campbell et al. 1990), 4) data management and analysis techniques, and 5) derived outputs (Meyer et al. 1990). During 1990, a national monitoring strategy was developed (Heck et al. 1991). In the second stage of the program (1991) in-depth examinations were conducted of several areas critical to the planning and implementation of the 1992 Pilot Project: 1) statistical design options, 2) measurements associated with specific indicators and assessment endpoints, 3) sampling protocols, 4) cooperation with NASS, 5) logistics, 6) total quality management, and 7) information management. Discussion and re-examination of these areas will continue through 1992.

The 1992 Pilot Project will test aspects of the monitoring program with a limited suite of endpoints (indicators). Experience from the 1992 Pilot will be utilized to develop a regional demonstration of all program elements in the Southeast (1993), to implement an additional pilot project in EPA Region VII (1993) and to initiate cooperation in an integrated terrestrial pilot (1993). Assuming the pilots and regional demonstrations are successful, we anticipate being ready to implement specific components of the Program on a national basis in 1995 or 1996; funding levels will determine the degree of regional and national implementation. The implementation schedule for the Agroecosystem Program is shown in Table 1-3 and Figure 1-1 through 1995.

Table 1-3. Planned implementation of Agroecosystem monitoring and assessment across EPA regions.

| EPA Regions | Years (Funds in thousands)[1/] | | | | |
|---|---|---|---|---|---|
| | 1991 (300) | 1992 (800) | 1993 (2440) | 1994 (4060) | 1995 (6200) |
| 1-NE Boston | ---- | ---- | ---- | ---- | Pl |
| 2-NE New York | ---- | ---- | ---- | Pl | Pil |
| 3-NE Philadelphia | ---- | ---- | ---- | ---- | Pl |
| 4-SO Atlanta | Pl | Pil | De | Im | Im |
| 5-NC Chicago | ---- | ---- | ---- | Pl | Im |
| 6-SO Dallas | ---- | ---- | ---- | Pl | Im |
| 7-NC Kansas City | ---- | Pl | Pil | De | Im |
| 8-NC Denver | ---- | ---- | ---- | ---- | Pl |
| 9-WE San Francisco | ---- | ---- | Pl | Pil | De |
| 10-WE Seattle | ---- | ---- | ---- | ---- | Pl |

[1/] Pl Planning (write a peer-reviewed Project Plan)
Pil Pilot Project (1 or 2 states)
De Demonstration Project
Im Implementation in EPA Region (full implementation in megaregion)

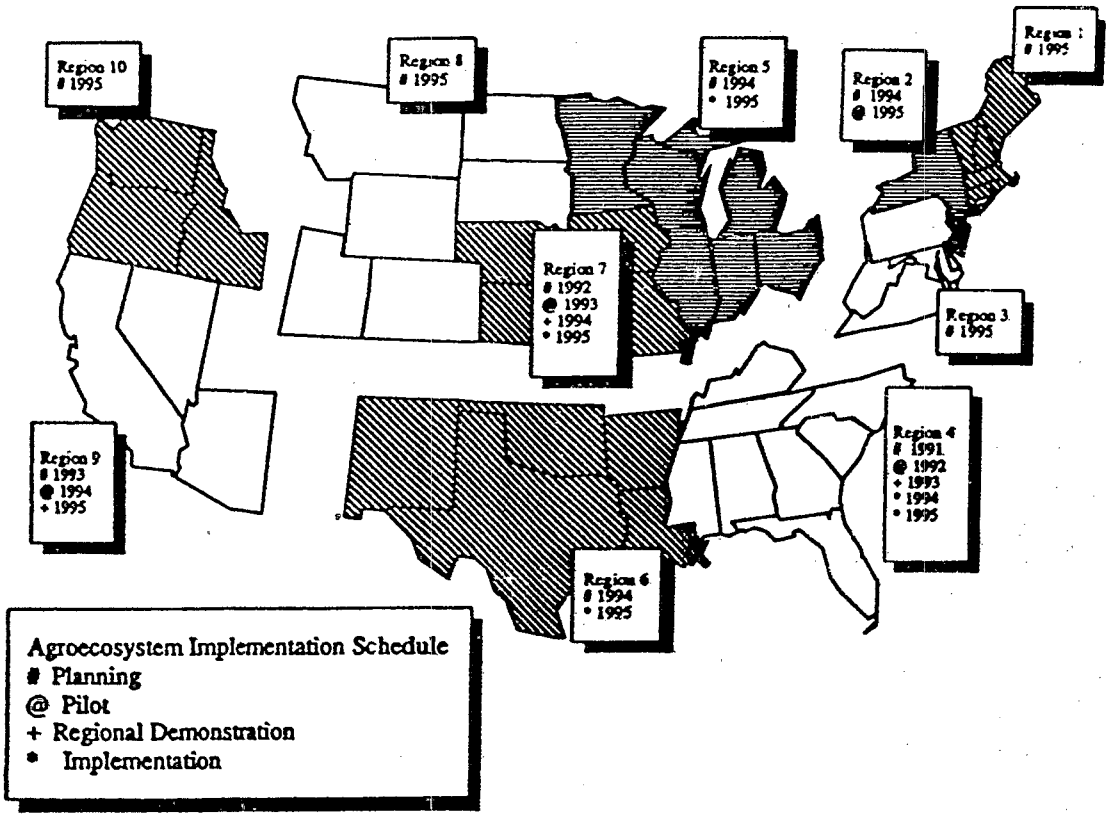


**Figure 1-1.** The Agroecosystem Implementation Schedule.

# 2. The 1992 Pilot Project: Rationale and Objectives

This section provides an overview of the rationale for the 1992 Agroecosystem Pilot Project and presents the specific objectives of the Project. The rationale is in keeping with the overall program approach and rationale outlined in Section 2 of the *Agroecosystem Monitoring and Research Strategy* (Heck et al. 1991).

## 2.1. Rationale

The Agroecosystem component of EMAP is being designed as a comprehensive monitoring program with the intent of increasing our knowledge of the status and extent of our national agroecological resources. It is also designed to identify associations between observed changes in ecosystem condition and a suite of stressor/exposure indicators.

Agroecosystems are managed intensively for human welfare and activities in the crop and non-crop components are often influenced by government programs (i.e., Conservation Reserve and Crop Quotas) and regulations (i.e., wetlands preservation and changes in permissible pesticide use). These intentional perturbations of agroecosystems provide a series of challenges to the establishment of an ecological monitoring program. Although the focus of the Agroecosystem Program is ecological, a full understanding of these intensively managed systems requires that both ecological and more traditional agricultural information be included.

It is essential to obtain certain information on management practices for crops and livestock, selected sociological and economic factors, and agricultural land use directly from the grower, because of the importance of grower inputs to agroecosystems. It is also essential to obtain specific samples, such as soil and water samples, and measurements, such as production efficiency, that relate directly to the actual quantification of ecological condition. Thus, the Pilot Project, and the eventual implementation of a national monitoring program, will be accomplished through a combined survey and sampling methodology.

Pilot projects will serve to resolve a number of relevant issues prior to regional or national implementation. These issues include the critical evaluation of indicators and assessment endpoints, the establishment of a sampling frame and sample sizes, the evaluation of logistics and quality control, the development of information management procedures (including provisions for data confidentiality), and, in cooperation with NASS, the establishment of data analysis, summarization, and reporting formats. The 1992 Pilot Project will address these issues at a geographic scale that is large enough to provide reliable answers to specific questions concerning the operation of the monitoring program, but is small enough to be physically and fiscally manageable. However, not every aspect of the national monitoring plan will be evaluated. For example, because of the status of indicator development and fiscal constraints, only a limited suite of indicators and assessment endpoints will be evaluated in the 1992 Pilot. Also, most components of the Pilot include research and development activities that will lead to the inclusion of specific indicators and procedures in regional demonstrations and in the national monitoring program.

The state of North Carolina was selected for the 1992 Pilot Project for several reasons, given in order of importance:

1. The physiographic diversity of the state is representative of the entire Southeastern region of the United States.

2. NASS is organized on a state-by-state basis and enumerator training is done in each state. By staying within a single state, we only need to work with a single NASS state organization. This simplifies the resolution of problems during the development of logistics, design, and implementation procedures. The training of NASS enumerators will be transferable, with only minor modifications, to each new state as states are added to the program.

3. The core staff of the ARG is located in Raleigh. For the first pilot study, this facilitates logistic activities.

## 2.2. Objectives

The 1992 Pilot Project is designed to provide information that will allow the evaluation of specific aspects of the Agroecosystem Monitoring Program. The Pilot will serve as a basis for the development of Regional Demonstration Projects and, where needed, of additional pilot projects to evaluate agroecological characteristics or logistic issues that are unique to specific regions. Specifically, there are four major objectives for the Pilot Project:

1. Critically 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.

2. Empirically evaluate an initial suite of indicators in order to:
   - Assess the ability of an indicator to address the assessment endpoints of interest
   - Establish an initial range of values for each indicator across the diverse physiographic regions in the state
   - Assess spatial variability of indicator values within and among sample units
   - Identify the usefulness and sensitivity of each indicator and assessment endpoint in determining ecological condition
   - Determine the cost-effectiveness for each indicator

3. Develop and refine plans for key components of the monitoring program.
   - Sampling
   - Logistics
   - Total quality management
   - Data analysis, summarization, and reporting
   - Information management
   - Health indices and their interpretation.

4. Develop and evaluate additional indicators that will address specific assessment endpoints.
   - Soil quality - biological component
   - Landscape structure
   - Water quality - groundwater component
   - Biomonitors of ozone impact on crops

The 1992 Pilot Project is not intended to be a full implementation of the Agroecosystem Monitoring Program, but will provide information essential to the successful development of regional demonstration projects. The Pilot Project represents the wise use of resources to fully consider issues critical for the success and implementation of the Agroecosystem Program.

# 3. Design and Statistical Considerations

Statistical considerations for the Agroecosystem 1992 Pilot Project fall under the two topics of sampling design and protocols, and data analysis. The basic issues associated with these topics were discussed in the 1991 Agroecosystem Monitoring and Research Strategy (Heck et al. 1991).

The ARG has two sampling plans under consideration for the 1992 Pilot Project. Two independent samples, one from each plan, will be used. This will provide cost and variance information from which a comparison of the two plans can be made. (Key information on temporal correlations needed for a more complete comparison of the plans cannot be obtained from a one-year pilot.) The basic sampling units in both plans are well-defined geographical areas that will contain an unknown number of agricultural fields. A protocol for obtaining a random sample of agricultural fields with known probabilities of inclusion is given. Some indicators require sampling the geographical area defined by the field. A protocol is given for this within-field sampling that will also provide information on relevant components of variance.

Data analysis will include (in addition to a simple statistical summary of the indicator results): 1) estimation of variance components to help determine future field sampling strategies, 2) correlation analysis to understand relationships among indicators as well as spatial patterns of the indicators, and 3) comparison of the variance and cost efficiencies of the two sampling plans.

## *3.1. Selection of the Pilot Sample Segments for Each Plan*

Each of the two sampling plans under consideration will use the NASS Area Frame segments as the basic sampling unit. The NASS area frame segments were defined by first stratifying the state of North Carolina based on intensity of agriculture (See Section 3.1.2). Each stratum is divided into Primary Sampling Units (PSUs). A random sample of PSU's are 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 and 1 square mile for agricultural strata.

One of the proposed Agroecosystem sampling plans is the EMAP Hexagon Plan. It uses the centroid of selected hexagons to identify the NASS segment that will be used for indicator sampling. The other sampling plan, called the Rotational Panel Plan, uses a subset of segments from the NASS June Enumerative Survey. Both plans will be evaluated in the 1992 Pilot Project.

### *3.1.1. The Hexagon Sampling Plan*

The EMAP hexagons (40 $km^2$) with their centroids in the state boundaries of North Carolina were selected as the hexagon sample for the 1992 Pilot. These 203 hexagons were located on a state map and were divided into four interpenetrating subsamples according to procedures outlined in the EMAP Design Report (Overton et al. 1991). One of the four subsamples was selected at random for the 1992 Pilot. Fifty-four hexagons were in the selected subsample, but three were over bodies of water not included in the NASS water strata. These three hexagons (numbers 8, 33 and 36 in Figure 3-1) were located in the large sounds lying between the mainland and the barrier islands and were dropped. The 51 remaining hexagons are distributed over 49 counties in North Carolina (Figure 3-1). The list of counties with the number of hexagons in each county is given in Appendix 2.

The coordinates of the centroids of these 51 hexagons were forwarded to NASS for identification of the NASS sample segments according to the following procedures.

- The primary sampling unit (PSU) that encompasses the centroid will be identified and its ID number, i.e., stratum, substratum, county and NASS replicate will be attached. The PSU will be assigned to a NASS technician who will divide it into segments according to NASS' standard criteria. Special care will be taken to ensure that the assigned technician does not know the location of the centroid within the PSU to avoid bias while delineating the segment boundaries.

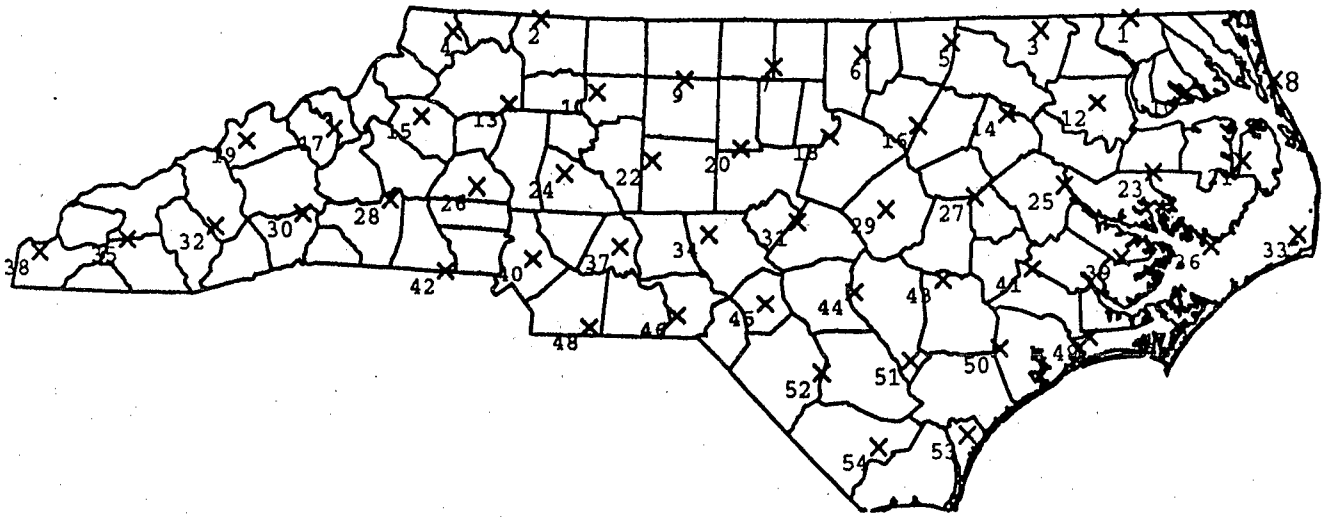

**Figure 3-1.** Hexagon subsamples for use in choosing the NASS Segments; three of the 54 hexagons (8, 33, 36) were not included because they were over large bodies of water; the 51 hexagons were found in 49 counties (see Appendix 2 for a list of counties).

- After segments within the PSU have been delineated, the segment containing the centroid will be identified and included as a sample segment.

- Characteristics to be described 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.

- The boundaries of the PSU and the selected segment are to be delineated on an aerial photo and on a county highway map for use by the ARG according to the NASS confidentiality guidelines. Duplicates are to be prepared for NASS field staff and the enumerators during data collection.

- Accurate time and cost records will be maintained for each step of the operations described above.

### *3.1.2. The Rotational Panel Sampling Plan*

The complete 1992 NASS sample for their June Enumerative Survey (JES) in North Carolina has 321 segments stratified as shown in Table 3-1. Only four of the 100 counties in North Carolina do not contain a sample segment.

The Rotational Panel sample for the 1992 Pilot consists of (approximately) a 20% subsample of the JES; one replication (replication number 4) from the sub-strata that have five replications, two (replications number 4 and 9) from the sub-strata that have 10 replications, and one (replication number 3) from the two sub-strata that have 3 replications. Thus, 65 segments from NASS' JES (Table 3-1) will be assigned to the Rotational Panel sample for the 1992 Agroecosystem Pilot. Reasons for selecting these particular replication numbers are:

Table 3-1. Stratification of NASS segments in North Carolina for 1992.

| Stratum | | Number of | | | |
|---|---|---|---|---|---|
| I.D. Number | Definition | Sub Strata | Reps | Segments | Pilot Segments |
| | | | | | |
| 13 | >50% Cultivated | 6 | 5 | 30 | 6 |
| 20 | 15-50% Cultivated | 14 | 10 | 140 | 28 |
| 31 | >20 home/mi$^2$ Ag-Urban | 5 | 10 | 50 | 10 |
| 32 | >20 home/mi$^2$ Commercial | 3 | 5 | 15 | 3 |
| 33 | >20 home/mi$^2$ Resort | 1 | 3 | 3 | 1 |
| 40 | <15% cultivated | 8 | 10 | 80 | 16 |
| 50 | 50 Non-Agricultural | 1 | 3 | 3 | 1 |
| Total | | | | 321 | 65 |

- Numbers 4 and 9 are the latest replications; they enter the sample in 1992 for the first time. Because the segments in the hexagon will be sampled for the first time, the comparison of the two designs will be free from any conditioning effects that might have resulted from any previous visits.

- Replicates 4 and 9 will remain in the JES sample for five years and will be available for re-measurement during that period.

- The latest replication (replication number 3) in Strata 33 and 50 was selected in 1991; it presumably will remain in the sample at least through 1993.

The 65 segments selected for the 1992 Pilot fall into 55 counties and provide a reasonable spatial representation (Figure 3-2) of the state.

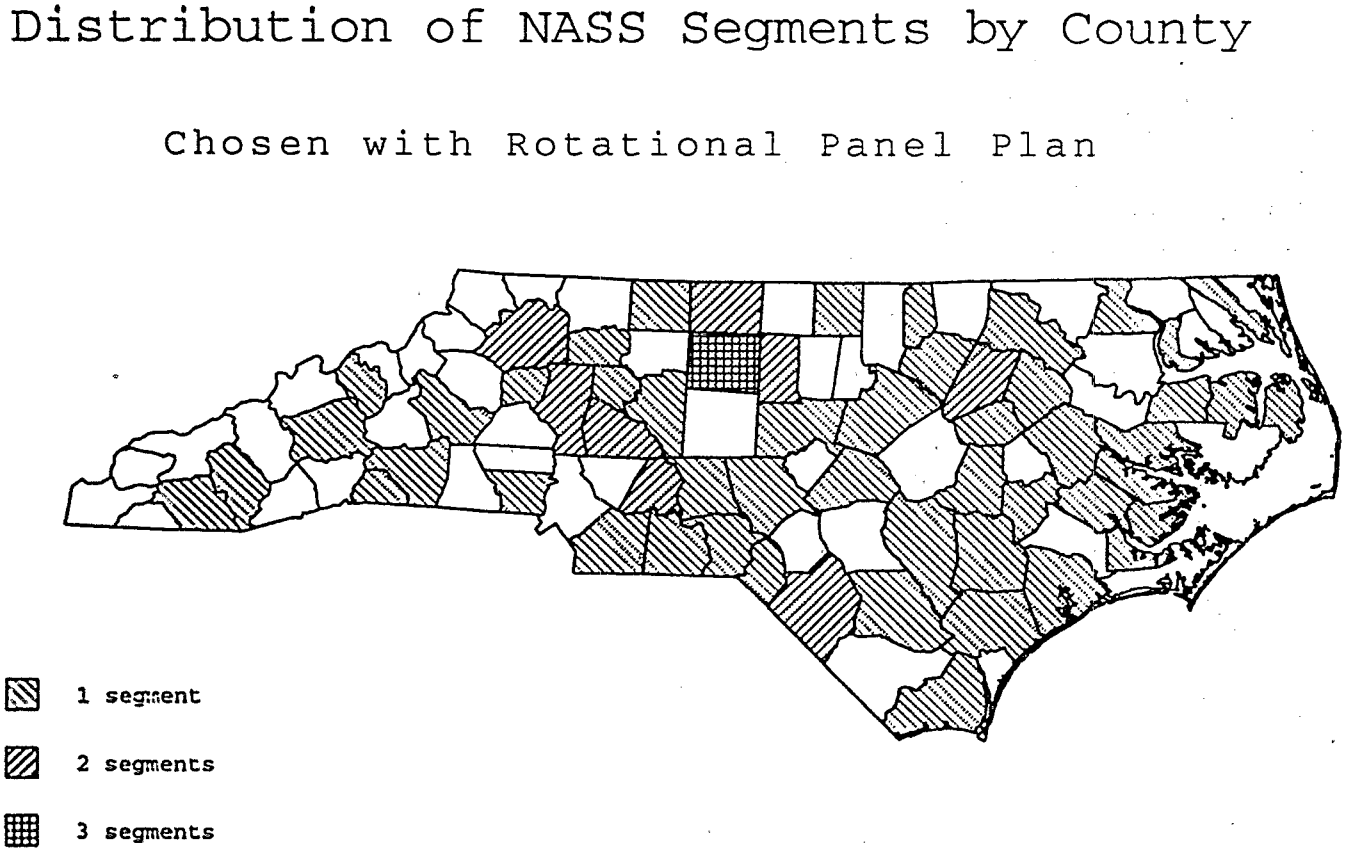


**Figure 3-2.** North Carolina Counties containing NASS Segments for 1992 Pilot; there are a total of 65 segments in 55 counties (see Appendix 2 for a list of the counties).

Maps and aerial photos will be prepared for the use of the North Carolina NASS Field Office for each of the 321 NASS sample segments in the 1992 June Enumerative Survey. If needed, duplicate aerial photographs of the segments selected from the 1992 pilot will be sent to the ARG. Records of the cost of these photos and maps and the cost of their preparation will be maintained.

### *3.2. Evaluation of the Two Plans*

Both cost and precision will be considered in evaluating the relative efficiencies of the two sampling plans. Because the two sample sizes differ slightly, efficiencies will be expressed in a standardized manner such as information per unit cost.

Because the Pilot is a one-year test and EMAP is a long range program, comparisons from the Pilot will not provide information on the relative efficiency of the two sample plans for estimation of changes or trends over time. Consideration of the relative efficiencies for the estimation of time trends must be based on theoretical results (e.g., Lesser 1992) or simulation rather than empirical studies (1992 Pilot).

### *3.2.1. Cost Comparisons*

To be sure that every applicable cost is included, each step in the survey process for each Plan will be identified and placed in its proper sequence in a flow chart. Records of costs at each of these steps will be maintained. NASS will maintain records of costs for operations they perform such as segmentizing the hexagon sample, delineating sample segments on aerial photos, and visiting sample sites. The ARG will maintain costs for operations they perform. The types of activities required to prepare the sample have been noted in Section 3.1. There will be similar field costs in training enumerators and in collecting the data. The entire field cost for the Hexagon sample will be assigned to that Plan since it is outside the scope of the regular JES. Costs assigned to the Rotational Plan sample will be prorated to include miscellaneous costs associated with the conduct of the survey.

Finally, the cost of processing the data, making the appropriate population estimates for the indicator variables and estimates of their variances will be identified. Because the Rotational Panel sample will be a full replicate of the NASS sample in North Carolina, the estimation procedures and variance formulae already developed by NASS will apply. The Hexagon sample will not be stratified and will require estimation procedures that have been worked out by the EMAP, Statistical Design Team.

There should be little or no incremental cost in preparing the Rotation Panel sample. NASS may choose to allocate pro rata costs for the development of the JES sample and perhaps even some costs for the development of the NASS area frame in North Carolina. These costs may have

to be negotiated but whatever they are determined to be, they will be considered in the comparison with the Hexagon Plan.

### *3.2.2. Estimates of Precision - The Hexagon Sample*

Estimation procedures for the EMAP Hexagon sampling design are being developed by the EMAP Statistical Design Team. The approach relies on the Horvitz-Thompson estimation (Horvitz and Thompson 1952). The estimation procedures presented here are extracted from their reports.

Although the actual Hexagon sample consists of NASS segments, the selection process is by means of the centroid of the hexagons. Thus, segments are selected with probability proportional to their area; the inclusion probability is given as

$p_i = a_i/A$, and the weight

$w_i = 1/p_i$

where $p_i$ is the probability of selecting the $i^{th}$ segment within the hexagon, $a_i$ is the area ($km^2$) of the $i^{th}$ segment, A is the area of the large hexagon (~650 $km^2$) and $w_i$ is the sampling weight associated with that segment.

The Horvitz-Thompson (HT) formula for estimating a population total, $\hat{T}_y$ , for any attribute y, is given as

$$\hat{T}_y = \sum_{i \in S} w_i y_i$$

where the summation is over the set of sample segments, S, in the population of interest, where $w_i$ is the sampling weight and $y_i$ is the value of the attribute for the sampled segment. The number of units in the population is estimated by setting $y_i = 1$.

The HT variance formula provides unbiased estimates of variance if all pairwise probabilities are positive. Systematic sampling has a large number of zero pairwise inclusion probabilities. A modification of the variance formula has been shown to perform satisfactorily where the pairwise inclusion probabilities, $\pi_{ij}$, have been approximated (Stehman and Overton, 1987) by

$$\pi_{ij}=\frac{2(n-1)\pi_i\pi_j}{2n-\pi_i-\pi_j}$$

from which

$$w_{ij}=\frac{1}{\pi_{ij}}.$$

The variance formula with this approximation is:

$$\hat{V}(\hat{T}_y)=\sum_{i\in S} y_i^2 w_i(w_i-1)+\sum_{i\in S}\sum_{\substack{j\in S\\ j\neq i}} y_i y_j(w_i w_j-w_{ij}).$$

It has been suggested recently that the Yates-Grundy estimator of variance might be more appropriate. This suggestion will be investigated by the EMAP, Statistical Design Team. Also, procedures are being developed to determine variance of the estimates empirically by means of facsimile population bootstrap (Overton 1991).

Because the segment is not a standard size, there is little interest in estimating a mean per sampling segment. Rather, interest will be in estimating population totals, or means for some standardized unit such as per acre, e.g., average yield per acre. Standardization to a per unit basis can be handled two ways. The appropriate population estimates of mean per standard unit are ratio estimates in which both the numerator and the denominator are random variables. Because no stratification is involved, the ratio estimate for the Hexagon sample is simply the estimated total production of, say corn, in a given universe divided by the estimated acreage of land planted in corn for grain in the same defined universe. The estimate of variance is an approximation based on the Taylor Series expansion and, therefore, is biased. However, in large

samples the bias is negligible. For some purposes the standardization to a per unit basis will be done at the sampling unit level (e.g., field yield divided by field acreage). In these cases the yield per acre will be treated as a variable in the HT estimation.

In the Hexagon Plan *per se,* post-stratification of the sample segments will not be used. However, for complete comparison of the two plans the effects of post-stratification will be investigated. Post-stratification will change the form of the inclusion probabilities.

### *3.2.3. Estimates of Precision - The Rotational Panel Sample*

Estimates of population quantities on variables of interest and estimates of their variances from Rotational Panel sample data have been worked out by NASS and can be applied directly. Estimates will be expanded to the population by applying the appropriate weights to the sample data in each substratum and adding up the substratum totals to provide an estimate for the region. Similarly, the variance of the estimate will be based on standard formula for a stratified random sample. Population estimates that are obtained as ratio estimates will require an approximation of the variance, as discussed in 3.2.2, but the component variances will be the appropriate variance formula for a stratified random sample.

## *3.3. Within Segment Sampling Protocols*

Field sampling can be divided into two parts: selecting the fields within the segments and taking the measurements within those fields. The individual components of variance for these two sources of variation will be explored during the Pilot.

### *3.3.1. Field Selection*

During the June Enumerative Survey (JES), NASS enumerators will obtain 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 and its identification number and

acreage recorded. For the 1992 pilot eligible fields will be defined as the planted acreage in any field that does not contain the crops listed in Table 3-2. All inferences made in the pilot will be to this population. The information will be used to select a subset of fields over all segments in the Hexagon Plan and over all segments within a given stratum for the Rotational Panel plan.

Table 3-2. Crops ineligible for selection in the Agroecosystem 1992 Pilot.

| |
|---|
| Permanent Pasture |
| Orchards |
| Vine Fruits |
| Christmas Trees |
| Other woody perennial crops |
| Greenhouse Plants |

A systematic sample with a random start will be used to select fields for inclusion in the pilot with probability proportional to size. Fields within sampled segments will be ordered arbitrarily first by crop and then by segments (for a given stratum for the Rotational Panel sample). All fields that contain crops that have not been excluded from the 1992 Pilot will be included in the ordering. The ordering by crops is to ensure that each crop is selected at least once as long as its acreage is greater than the step size used in selecting the sample. If a field has been double-cropped and both crops will be harvested for grain, then the crop pair will be treated as a separate entity in the ordering of the crops. For example, in a field planted consecutively with both wheat and soybean, each to be harvested for grain, the ordered list created for the systematic sampling might appear:

| Field # | Crop |
|---|---|
| i | wheat |
| i+1 | wheat |
| ... | |
| i+j | wheat |
| i+j+1 | wheat-soybean |
| ... | |
| i+j+m | wheat-soybean |

i+j+m+1 soybean
i+j+m+2 soybean
...

In double-cropped fields where only one crop was harvested for grain, the harvested crop will be used for determining the ordering.

For the sampled segments we will define

- s as the number of sample segments
- f as the number of fields, and
- $a_j$ as the planted acreage in the field, where the subscript indexes the fields after ordering.

The cumulative acreage of all fields in the sequence up to and including field i is

$$A_i = \sum_{j=1}^{i} a_j$$

and the total acreage is

$$A_T = \sum_{j=1}^{f} a_j$$

Preliminary analyses of field size distributions in North Carolina suggests that an average sample size of three fields per segment will provide a reasonable representation of the major crops. This implies that the step size, k, in the sequential sampling needs to be:

$$k = int\left(\frac{A_T}{3s}\right)$$

where int(c) denotes largest integer less than c. This step size will be adjusted to provide the desired sample size when the land use data from the JES are available. A random integer between 1 and k will be chosen as the random start and then every integer m+ck, c=0,1,2, . . . until m+ck > $A_T$, will designate a selection. Field i is selected for sampling if

$$A_{i-1} < m+ck \leq A_i \quad \text{for some } c.$$

In double cropped fields where the acreage of the two crops differ, the maximum of the two planted acreages will be used in field selection.

The fields that have been selected will be identified and marked on the aerial photographs for use by the NASS enumerators in collecting the field data.

An alternate way to select the fields for indicator sampling is to expand the fields by their expansion factor (the inverse of their selection probability) prior to selection. This provides a self-weighting sample and simplifies the estimation of sample variances, means and population totals. The ARG is currently exploring this possibility.

### *3.3.2. Sampling Within Fields*

Soil sampling to determine soil physical and chemical properties and nematode densities will require within-field sampling. A sample of 20 soil cores composited for each field will provide sufficient soil for both physical and chemical analysis, and nematode density assays. Whereas it may be desirable to have a method that would sample the entire field, field size often will make this impractical. Consequently, the entire field will serve as the soil sampling unit only if it is five acres or less in size. For fields larger than five acres, a pseudo-random five-acre subregion of the field will be chosen. If a field is chosen randomly for the collection of more than one soil sample, an independent five acre subregion will be chosen for each sampling. The five-acre subregion will be sampled with 20 soil cores taken at equal distances along a 100-yard transect that represents the diagonal of the five-acre subregion. The diagonal transect, as opposed to some other method such as a grid placement, was chosen primarily because of its ease of implementation.

NASS' procedures for locating objective yield plots will be adapted for use in locating the sampling transect. According to these procedures, if the field is less than sixty acres the field is divided into quarters. If the field is larger than sixty acres it is divided into ninths. The objective yield plot is then located in only one of these subregions. The subregion that is

selected for location to the objective yield plot is identified by the first corner of the field that the enumerator encounters as he or she approaches the field. While this is not a random choice, in NASS' experience they have found this procedure to be satisfactory.

The modifications to the procedure for locating the transect for the soil samples for the Agroecosystem Pilot are as follows. If the field is five acres or less in size, it will not be subdivided before location of the transect; otherwise, subdivision of the field will be as described above. A random point will be located in the subdivision based on a random number of rows and paces along rows from the corner of the selected subsection. If rows are not present in the field, random paces will be used. The enumerator using NASS procedures will locate the point in the field. This point will designate the midpoint of the transect to be used for soil sampling, and the transect will run at a 45° angle to the direction being walked by the enumerator (Figure 3-3). From this center point on the transect, the enumerator will take 10 soil cores in each direction along the transect with the first core being 2.5 yards from the center point and each succeeding core being an additional 5 yards 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 yards to the northeast and 50 yards to the southwest.

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. See Figure 3-4. This will continue for every boundary encountered until the entire distance of the transect has been traversed.

To ensure that the sampling is not biased by the subjective placement of the core, enumerators will mark the end of each 5-pace interval with a wooden stake, and before sampling they will lay a marked stick along the transect at the stake. The soil sample will then be taken at either 1.5 feet or 3 feet from the stake, depending on whether the stake is odd or even. Appendix 6 gives additional detail on this sampling procedure.

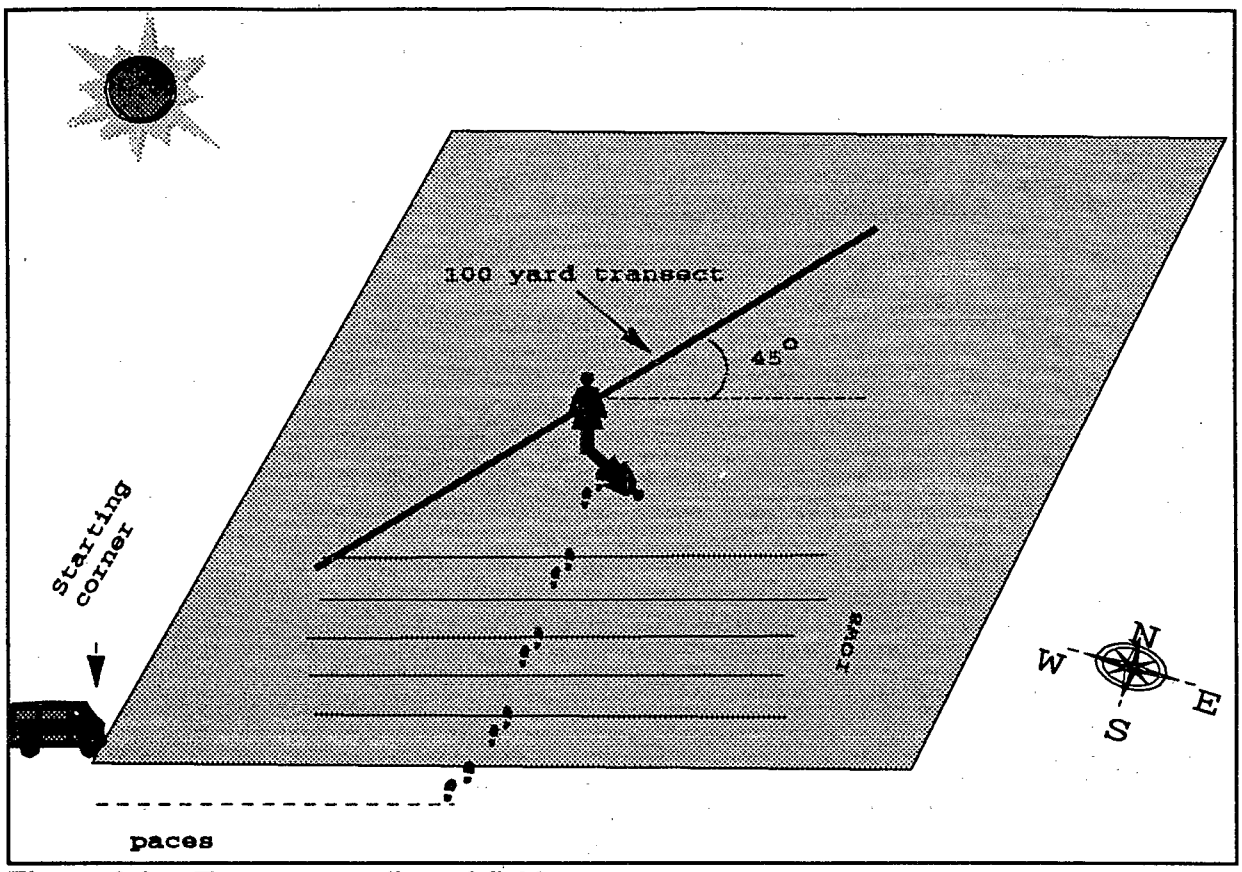


**Figure 3-3.** Transect sampling of field.

### *3.3.3. Sources of Variation in Field Sampling*

There are three principal sources of variation in field sampling: between-field variation, within-field variation, and the variation in laboratory analyses. To obtain these components of variation the following design will be used. Except for differing numbers of segments, the same procedure applies to both sampling designs.

Sample segments will contain, on average, 3 sampled fields. For soil samples, every $k^{th}$ field will be sampled twice to get an estimate of the within field variability. This will be accomplished by choosing a second independent transect from the same field using NASS protocols. The next most accessible corner of the field is chosen and the sampling is repeated on a new transect defined with a new starting point. Considering only the transects from these

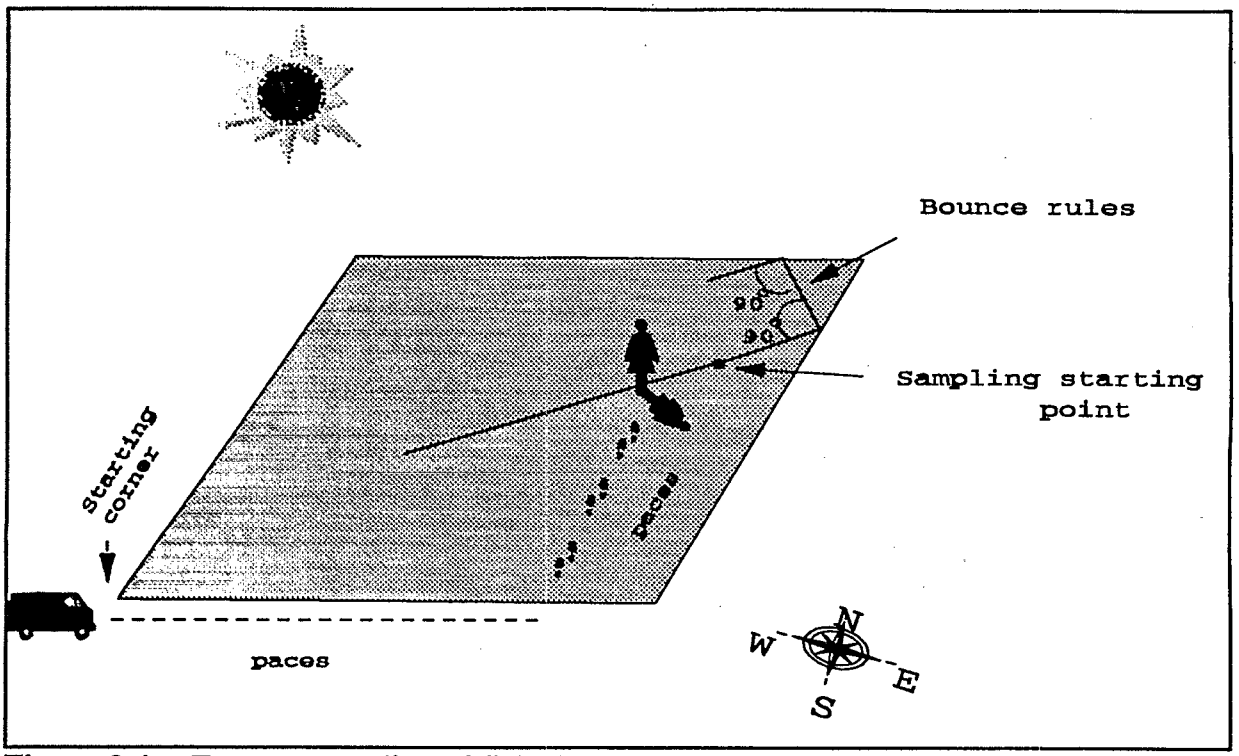


**Figure 3-4.** Transect sampling of field (Bounce rules).

twice-sampled fields, the soil sample from every $s^{th}$ transect will be split for duplicate laboratory analysis. To ensure enough soil for the split sampling, two cores will be drawn at each sampling point in these particular transects.

Let N be the number of fields sampled in the pilot; this should be about N=348. Using the ordering of the fields given previously, every $k^{th}$ field will be sampled twice with independent transects. (Other fields will be sampled twice simply due to their size being greater than the step size in the field sampling process). This will give 2N/k soil samples from these twice-sampled fields. (There will be $(\frac{k-1}{k})N$ soil samples from the other fields.) Of the 2N/k soil samples from the twice-sampled fields, every $s^{th}$ soil sample will be split for laboratory determinations. This procedure gives N/k and 2N/ks degrees of freedom for the "samples in fields" and "determinations in samples" mean squares. The two mean squares have equal degrees of freedom if s=2, which seems desirable. With N=348 and s=2, the analysis of variance (ignoring strata) is found in Table 3-3.

Table 3-3. Degrees of freedom for field sampling components of variance.

| Source | df | (k,s)=(5,2) | (k,s)=(6,2) |
|---|---|---|---|
| Among fields | N-1 | 347 | 347 |
| Samples(fields) | N/k | 70 | 58 |
| Def(samples) | 2N/ks | 70 | 58 |
| Total Soil Samples | $N(\frac{ks+s+2}{ks})$ | 487 | 464 |

Current plans are to use k=6 and s=2; that is, every sixth field sampled will use two independent transects and the soil from the second of each of these transects will be split to provide duplicate laboratory determination for soil chemical analysis and nematode assay. These numbers may be modified by budget considerations. Additional known samples to determine laboratory accuracy will also be included (see Appendix 7, Section 5.2.5).

### *3.3.4. Selection of Farm Ponds and Wells for Water Quality Sampling*

Current plans are to sample farm ponds and wells for water quality analysis. The budget and logistic constraints limit this sampling to about 50 segments. This is approximately the number of segments associated with each of the two sampling plans (65 in the Rotational Panel Plan and 51 in the Hexagon Plan) so that the present plan is to limit the water quality sampling to only one of the two plans. Currently, however, there is no information on the distribution of farm ponds and wells across the state and the frequency with which they will be associated with the randomly chosen fields. Information on the number and location of ponds and wells within each selected segment will be obtained from the JES. Since pond and well sampling will not be done until November (See section 5.3 and 6.3), the ARG is postponing until after the JES decisions about which set of sample segments will be used and how ponds and wells will be selected within the segments.

### *3.3.5. Sampling within Farm Ponds and Sources of Variation*

Sampling within farm ponds is still in the early stages of development. Two methods are being discussed. The first method uses the more conventional procedure of taking samples from a boat at several places and depths in some prescribed manner (see 5.3 for further details). While it is recognized that sampling from a boat is preferable, and may be necessary, the logistics of having a boat available to the enumerators and transporting the boat to all ponds makes the procedure difficult. The second method attempts to avoid the logistical problem of having a boat available. A long pole with a water sampler attached would be used to obtain water samples at some fixed distance (say 24 feet) from the shore at several points around the pond. Since most farm ponds are relatively small, this composite water sample may provide a reasonable representation of the pond. However, there are concerns that this method will produce biased estimates. If preliminary testing shows that this procedure or some similar procedure is feasible, the two methods, boat sampling and shore sampling, will be compared in the Pilot.

Whatever method is adopted for choosing the ponds, the pond sampling plan will include a subset of segments (approximately 25) on which the boat and shore sampling methods will be compared and components of variance estimated. (In the remaining segments, only the shore sampling method will be used.) The experimental design for this study will be structured as follows (except the numbers may vary). Two ponds will be selected within each of these 25 segments and on each pond both methods of obtaining the water sample will be used. In one of the ponds, randomly chosen, a water sample will be obtained by compositing the samples from the two water sampling methods; in the other of the two ponds, two independent composite water samples will be obtained by each water sampling method. This design will provide for a direct comparison of the two water sampling methods and allow for estimation of variance between ponds within segments and within pond sampling variability for each method.

### *3.4. Analysis*

Analysis of the 1992 Pilot Project data will address four major topics: 1) statistical summary of the indicator results; 2) variance estimation including assessment of the levels of precision attained, variance component estimation, and consideration of alternative field sampling strategies; 3) analysis of the indicators and their component variables including the correlations among variables as well as the spatial correlations and patterns of individual indicators; and, 4) comparison of the two sampling designs.

#### *3.4.1. Statistical Summaries*

The statistical summary of the indicator data will convey the population estimates of the present status of the indicators for the geographical region covered by the 1992 Pilot. A detailed listing of the summary statistical data we expect to develop from the 1992 Pilot is shown in Appendix 3.

The Pilot alone will not provide information on changes or trends. The primary purpose of the statistical summary is to develop the methods for the annual statistical summaries. The indicator data will be summarized by means of the estimated population cumulative density function (cdf). The cdf for a particular indicator presents the proportion of the population (in the Agroecosystem Pilot case, the proportion of area of cultivated land) that has values of the indicator less than or equal to any specified value. Figure 3-5 illustrates a hypothetical cdf for electrical conductivity of soil (mmhos/cm) in North Carolina. To the degree the estimated cdf accurately reflects the population cdf, it conveys all the information about the distribution of the indicator values: location, dispersion, and shape of the distribution. To facilitate interpretation of each cdf, key quantiles of the distribution will be presented in tabular form. Construction of the cdf must take into account the differential weights of the sampling units.

A problem arises in estimating a population cdf when the indicator variable is subject to appreciable measurement error, as is expected for the Agroecosystem indicators. Without

adjustment the empirical cdf, obtained from the indicator data, estimates an overly dispersed cdf. Methods of disentangling the population cd from measurement error are being developed by the EMAP Statistical Design Team.

It is anticipated that the two sampling plans will provide similar information on the population distribution of the indicators. The estimated cdf from the two sampling plans will be compared with nonparametric tests and, if compatible, a combined cdf will be presented. Other methods of displaying key features of several cdfs, such as box-plots, may facilitate their comparison and will be explored. Figure 3-6 illustrates the box-plots for three distributions. In each case, the rectangular box encompasses the central 50% of the distribution with its top and bottom edges denoting the 75th and the 25th percentile, respectively. The middle line is the median and the two lines extending vertically from the box mark the 95th and 5th percentiles. Outliers beyond these percentiles are marked with asterisks.

In addition, the statistical summary will include displays of the spatial patterns of key indicators. The displays will be of sufficient resolution to develop contour plots or shaded maps of the value of the indicator (See figures 3-7a and 3-7b). The precision of the kriged surface can also be displayed.

### *3.4.2. Variance Estimation*

Estimation of precision (variance) of population estimates is determined by the sampling design. For each sampling design, the precision attained by the 1992 pilot survey for each of the various population estimates will be computed as appropriate for that design. These measures of precision will be repeated in the statistical summary and will be used to compare the variance efficiencies of the two designs for estimation of status and to help in defining attainable data quality objectives for measures of status for the Agroecosystem Program. For comparison of variance efficiencies, for definition of data quality objectives, and for measures of change or trend, assumptions on the magnitude of temporal correlations will have to be made.

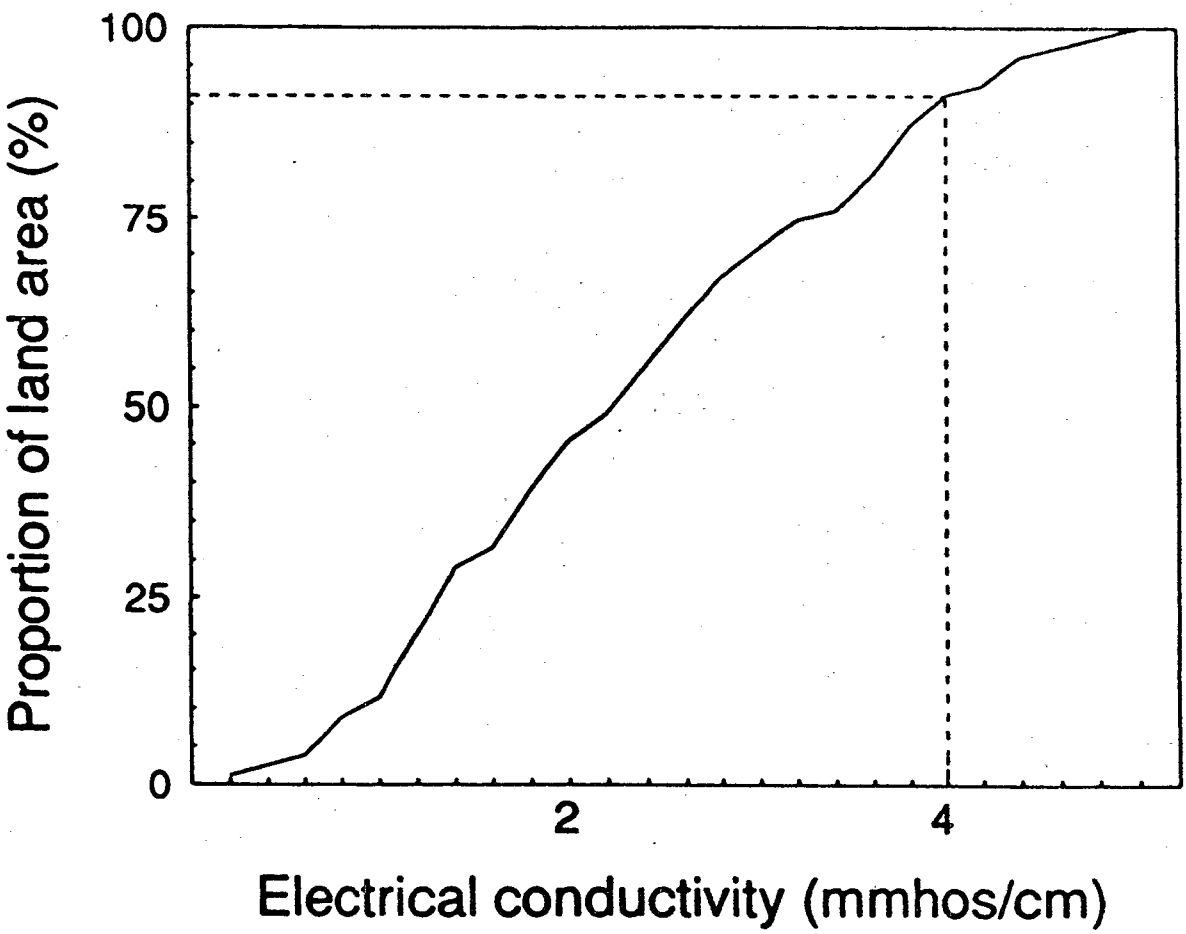


**Figure 3-5.** Hypothetical cumulative density function (cdf) for electrical conductivity of soil in North Carolina.

Components of variance will be estimated for key indicator variables. The components of variance will be used with cost estimates to explore strategies for future allocation of sampling effort: numbers of fields per segment, samples per field, and determinations per sample. Since several indicators are involved, each with its own variance component structure, any sampling strategy adopted would necessarily be a compromise. Excessively large variance components may suggest problems in the definition of specific indicators.

### *3.4.3. Analysis of Correlation Structure*

Analysis of the correlation structure of the indicators will be addressing four basic questions:

- What are the relationships among the indicators and what implications do these relationships have with respect to defining the set of indicators to be used?

- Do the principal components of the indicators provide any meaningful suggestions about the definition of health of the agroecosystem?

- What is the nature of the spatial correlation structure of the indicators?

- Is there also potential to use double sampling techniques to enhance the Agroecosystem information with the correlated information collected on other variables from the full JES sample of 16,000 units a year?

Principal component analysis and biplots will be used to investigate the relationships among the indicators. Correlations reveal pairwise linear association of the indicators. Principal component analyses and the biplot reveal multivariate associations; groups of indicators that tend to behave similarly within sets. Similar behavior of several indicators many indicate redundancies in the definition of indicators or may be suggesting a definition for one dimension of health of the ecosystem. Different groups may be addressing different dimensions of health.

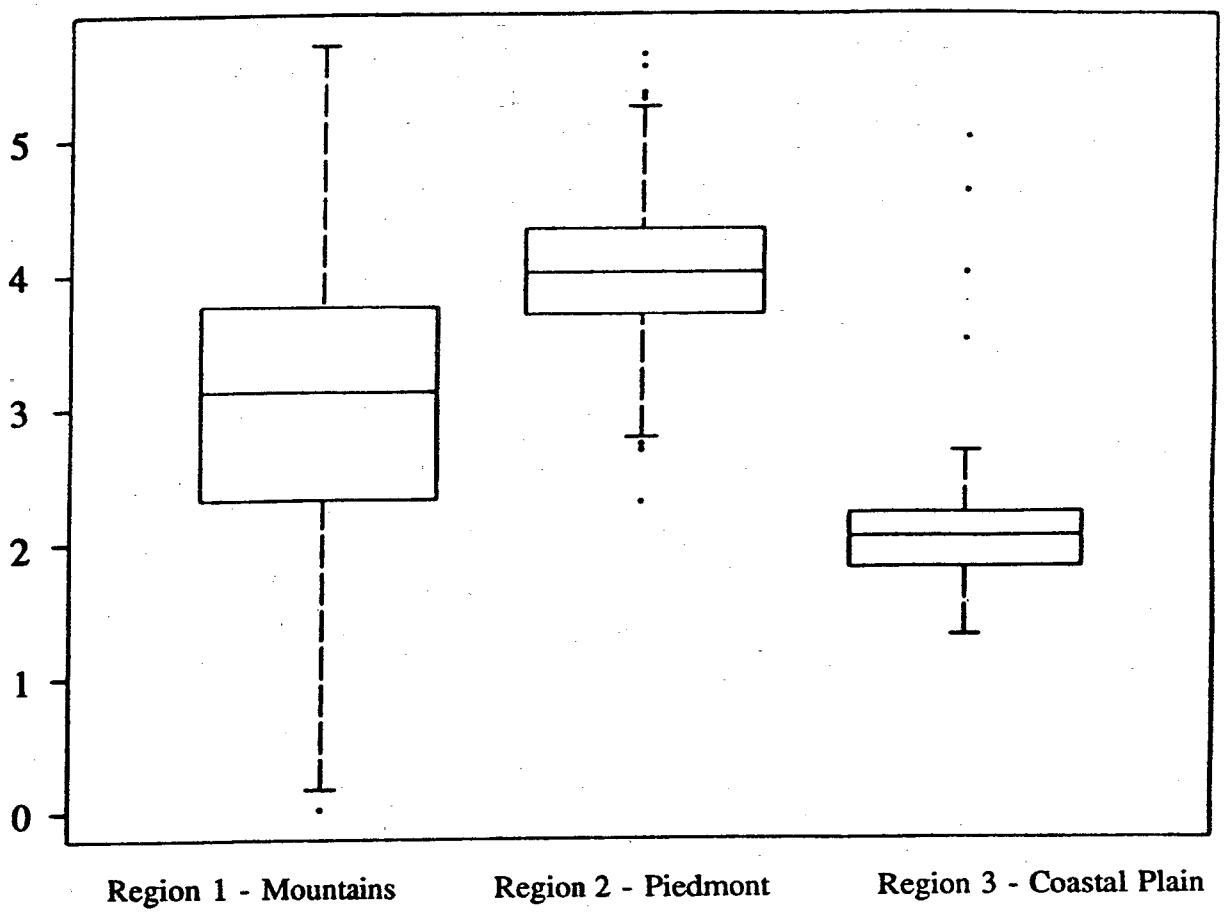


**Figure 3-6.** Examples of box-plots for the electrical conductivity of soil in three Regions of North Carolina.

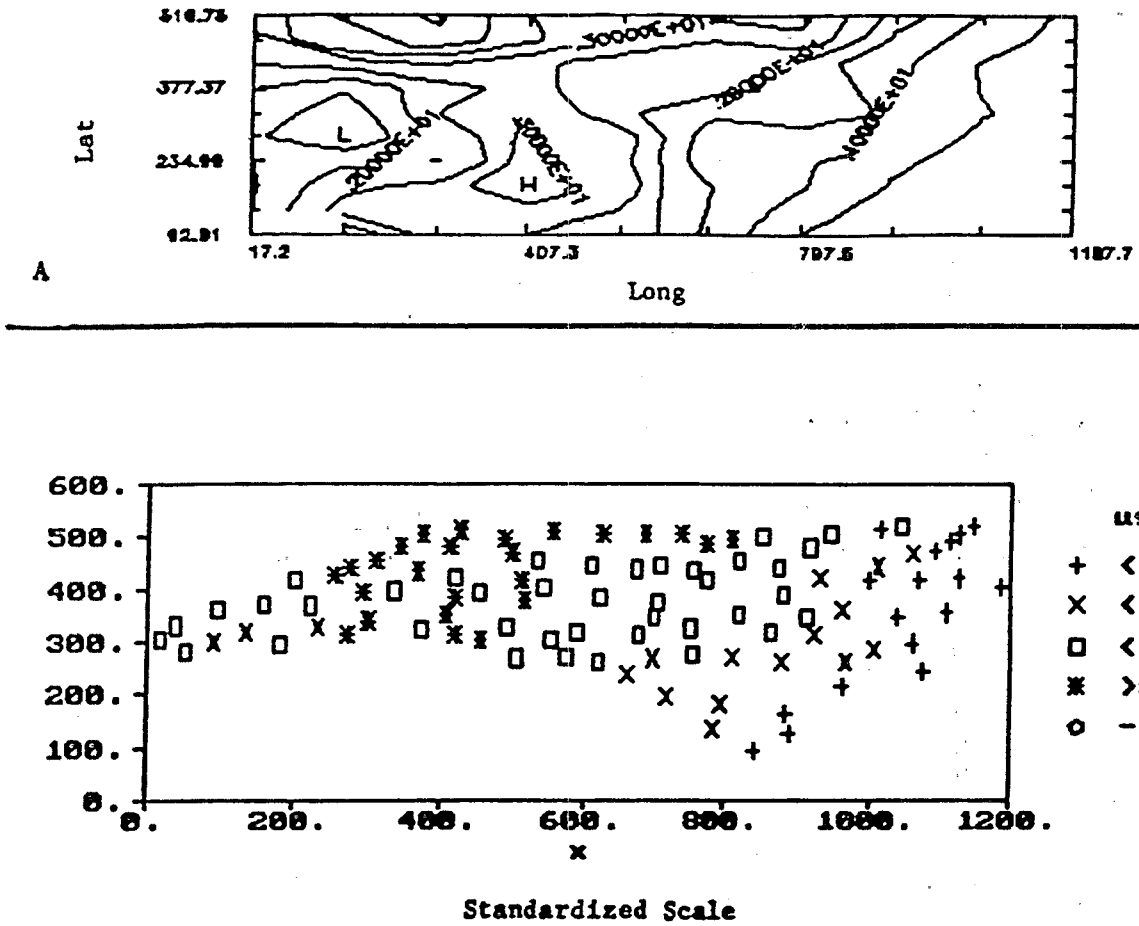


**Figure 3-7.** A, Kriged estimates of USLE over North Carolina (an example only); B, Display of spatial patterns.

Interpretation of the principal component analysis will require close collaboration with the scientists.

The nature of the spatial correlation structure will be investigated by fitting variogram models that depend on the spatial relationships of the observations. This will require knowledge of the site locations and must be done in conformity with the confidentiality requirements of NASS. The variogram information will be used in constructing spatial displays of regional patterns. The spatial correlation structure and some method of spatial interpolation may also be used as one possible way of masking the true locations of the sample points (maintaining confidentiality) while retaining data that have properties similar to the original observations.

Correlations between the agroecosystem indicator values and variables measured by NASS in the full JES sample will be explored to determine if any of the correlations are of sufficient magnitude to warrant use of double sampling techniques.

### *3.4.4. Comparison of the two Sampling Plans*

Both sampling designs, the Hexagon Plan and the Rotational Panel Plan, sample exactly the same reference population and both are proper probability samples. Consequently, the estimates of population total or means obtained from the two designs are estimating the same population quantities; any differences would be due to sampling error. The primary differences in the two designs are the use of stratification and the rotation of segments out of sample after five years. Both stratification and the systematic spatial coverage may affect precision of all estimates. The precision of the estimates of status for the two plans will be adjusted for differences in sample size before being compared. The direct effect of stratification on precision will also be determined by applying post-stratification to the Hexagon sample.

The rotation of the sample segments will affect precision estimates of change or trend; The magnitude of the effect will depend on the magnitude of the temporal correlations. The temporal

correlations cannot be estimated from a single year study so that any comparisons of precision of change or trend estimation will necessarily require assumptions about the temporal correlation.

The costs per observation will differ considerably between the two plans due to the closer coordination of the Rotational Panel Plan with the ongoing JES. Costs will be determined for each sampling plan and combined with the measures of precision to obtain information per unit cost for each indicator population estimate.

This empirical comparison of the two designs will be limited because only one realization of the sampling process will be available and because variances in the limited region covered by the 1992 Pilot may not adequately reflect variances for other regions. Consequently, simulation will also be used for a more thorough comparison of the designs and these results will be compared with the theoretical work of Lesser (1992).

# 4. Assessment Endpoints and Indicators

The goal of the Agroecosystem program is to monitor and assess the long-term status and trends in the health of the nation's agricultural resources from an ecological perspective. Because agroecosystem health cannot be measured simply and directly, a number of assessment endpoints and associated indicators have been proposed that, when monitored, will describe collectively the overall condition of agroecosystems.

## 4.1. Societal Values, Assessment Endpoints, and Indicators

For the purposes of EMAP, the ARG has identified three **societal values** that are of primary importance in determining agroecosystem condition. These societal values are: 1) supply of agricultural commodities, 2) quality of natural resources, and 3) conservation of biological resources (Figure 4-1). **Supply of agricultural commodities** addresses the ability of an agroecosystem to provide adequate crop and livestock yield and quality over the long term. **Quality of natural resources** is the freedom of natural resources from harmful levels of substances such as trace metals, pesticides, fertilizers, pathogens, salts and pollutants in one or more components of the agroecosystem. These are present usually as a result of human activities, may be persistent and mobile in the environment, have potential to bioaccumulate in the food chain, or have potential short- or long-term adverse effects on biota, including humans. **Conservation of biological resources** reflects the desire to maintain the ecological soundness of crop and non-crop components of the agricultural landscape as habitat for plant, animal and microbe species.

**Assessment endpoints** are quantitative or quantifiable expressions of the environmental value being considered in the analysis (Suter 1990). Seventeen assessment endpoints have been identified for possible use in the Agroecosystem monitoring program. These assessment endpoints and their relationship to the three societal values discussed above are shown in Table 4-1. These assessment endpoints address the agricultural and ecological aspects of agroecosystems

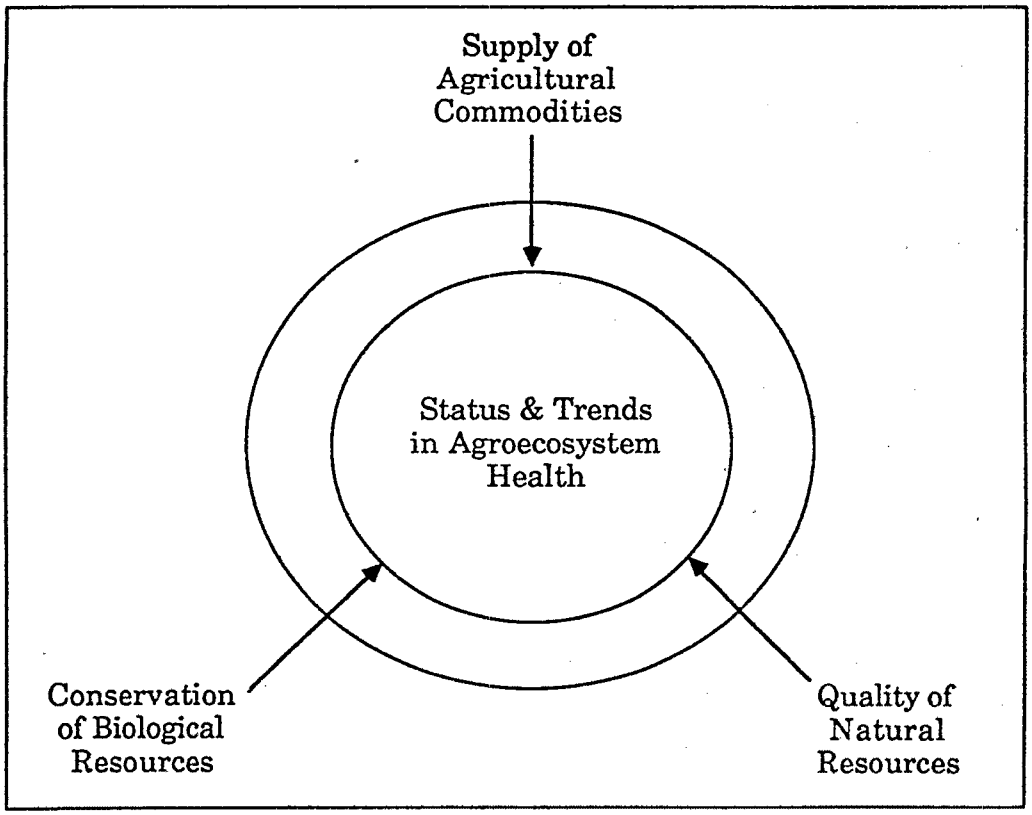


**Figure 4-1.** Agroecosystem societal values that will be addressed with a suite of indicators to determine the status and trends in agroecosystem health.

and have been selected through a process of consultation with experts and extensive discussions within the ARG over a two-year period (Heck et al. 1991). Although the list is comprehensive, it can be changed. Also, because of fiscal and logistical limitations, it may not be possible to retain. all of the assessment endpoints within the eventual regional and national monitoring program.

**Indicators** (measurements) are characteristics of the environment that, when measured, quantify the magnitude of stress, habitat characteristics, degree of exposure to stressors, or degree of ecological response to an exposure (Hunsaker and Carpenter 1990). Indicators serve as the basis for quantification of the assessment endpoints. For example, water-holding capacity, amount of erosion, and indices of soil biological activity are indicators that serve to quantify the assessment endpoint of soil quality.

**Table 4-1.** Association between the Agroecosystem assessment endpoints and societal values.

| Assessment Endpoint | Supply of Agricultural Commodities | Quality of Natural Resources [1/] | Conservation of Biological Resources |
|---|---|---|---|
| Crop Productivity | X | | |
| Soil Quality: Physical/Chemical | X | X | |
| Water Quality: Ponds and Existing Wells | X | X | |
| Land Use/Land Cover | X | | X |
| Agrichemical Use | X | X | X |
| Soil Biological Health (Nematode indices) | X | | X |
| Landscape Structure | | X | X |
| Groundwater/Well Comparisons | X | X | |
| Biological Ozone Indicator (Clones of white clover) | X | X | X |
| Socioeconomic Health | X | X | X |
| Pest Density | X | | X |
| Foliar Symptoms | X | X | X |
| Beneficial Insects | X | | X |
| Genetic Diversity | X | | X |
| Habitat Quality | | X | X |
| Wildlife Populations | | | X |
| Livestock Productivity | X | | |
| Nonpoint Source Loading | | X | X |
| Water Quantity (irrigation) | X | | |
| Other Biomonitor Species | X | X | X |

[1/] Air, soil, and water, including transport of contaminants into, within, and out of agroecosystems.

Four types of indicators are defined for EMAP. The relationships of these indicator types to the assessment endpoints are shown in Table 4-2. The four indicator categories are:

1. **Response indicator:** a biological/ecological characteristic measured to provide evidence of the condition of a resource at the organism, population, community, or ecosystem level of organization.

2. **Exposure indicator:** an environmental characteristic measured to provide evidence of the occurrence or magnitude of contact with a physical, chemical or biological stressor.

3. **Habitat indicator:** a physical, chemical or biological attribute measured to characterize the conditions necessary to support an organism, population, community or ecosystem in the absence of stressors.

4. **Stressor indicator:** a characteristic measured to quantify a natural process, an environmental hazard or a management action that results in changes in exposure or habitat.

## 4.2. Selection of Assessment Endpoints for The 1992 Pilot Project

One of the objectives of the 1992 Pilot Project is to evaluate empirically an initial suite of measurements or indicators which will address several of the selected endpoints for monitoring the ecological condition of agroecosystems (Section 2.2).

### *4.2.1. Rationale for Selection of Pilot Endpoints and Indicators*

Because the 1992 Pilot Project has several primary objectives (Section 2.2), a balance was required between the selection of assessment endpoints and other aspects of the project. Also, endpoints needed to be selected based upon the information derived from the Pilot which would aid in judging the suitability of specific measurements or indicators and upon the likelihood of

**Table 4-2.** Association between the Agroecosystem assessment endpoints and the indicator types.[1/]

| Assessment Endpoint | Indicator Types | | | |
|---|---|---|---|---|
| | Response | Exposure | Habitat | Stressor |
| Crop Productivity | X | | | |
| Soil Quality: Physical/Chemical | X | X | X | X |
| Water Quality: Ponds and Existing Wells | | X | X | X |
| Land Use/Land Cover | X | | X | X |
| Agrichemical Use | | X | X | X |
| Soil Biological Health (Nematode indices) | X | | | |
| Landscape Structure | | | X | |
| Groundwater/Well Comparisons | X | X | X | X |
| Biological Ozone Indicator (Clones of white clover) | X | X | | |
| Socioeconomic Health | X | X | | X |
| Pest Density | X | X | | X |
| Foliar Symptoms | X | X | | |
| Beneficial Insects | X | X | X | |
| Genetic Diversity | X | X | | |
| Habitat Quality | X | | X | |
| Wildlife Populations | X | | X | |
| Livestock Productivity | X | | | |
| Nonpoint Source Loading | | X | | X |
| Water Quantity (irrigation) | | | X | X |
| Other Biomonitor Species | X | X | | |

[1/] See definitions on page 4-4.

success in implementing associated indicators. This likelihood of success was judged on the basis of 1) the ability of NASS enumerators to collect the required survey data and samples, 2) the availability of analytical and assay procedures that fit within the quality and fiscal standards of the ARG, and 3) the ability of the ARG to utilize and interpret the data obtained.

The first criterion was essential because one element of the pilot project is to establish and refine the working relationship between the ARG and NASS. It is the current intent of the ARG that NASS enumerators will serve as the primary grower contact and as the primary field personnel for acquiring specific samples (e.g., soil, water, etc.). In the Pilot Project it will be essential to establish this as a viable and realistic approach.

The second criterion reflects the desire of the ARG to produce the best quality product (a pilot assessment of the condition of agroecosystems in a limited geographic area) within the constraints of available budget. Budgets often dictate what is and is not possible. The challenge to the ARG has been to assemble a suite of endpoints and indicators that is scientifically credible and informative within such fiscal constraints.

The third criterion acknowledges the difficulty of interpreting monitoring data in an integrated assessment that is intended to assess system health. Thus, the approach emphasizes key, critical areas in the ecological assessment of agroecosystem condition. Also, from the perspective of the design and statistics components of the pilot, indicators need to be selected that have a relatively clear, known interpretation so that variability within and among sample units could be analyzed and placed in the proper context.

### *4.2.2. Assessment Endpoints Selected for the 1992 Pilot Project*

Based upon the three criteria identified in section 4.2.1, five assessment endpoints were selected for initial implementation in the 1992 Pilot Project:

- Crop Productivity

- Soil Quality
- Water Quality
- Land Use
- Agricultural Chemical Use

All three societal values are addressed by this group of assessment endpoints. The specific societal values addressed by these endpoints are identified in Table 4-1.

The selected assessment endpoints will be quantified primarily via response, exposure and habitat indicators or measurement endpoints (Table 4-2). The specific, candidate indicators and measurements to be obtained during the pilot are identified in Section 5. The measurements needed to quantify these endpoints are generally well known. However, critical decisions must still be made concerning the specific measurements and techniques of data analysis related to the endpoints that will be appropriate for EMAP.

The assessment endpoints selected have both agricultural and ecological interpretations. The apparent emphasis on agricultural characteristics reflects the availability of a greater number of agricultural system attributes that can be readily characterized, because long-term monitoring of agricultural attributes has been carried out within agricultural systems. The ecological applications of the endpoints are also appropriate when the total agroecosystem is considered. As agroecology develops as a discipline and as the ARG continues to make progress in indicator development (see Sections 4.3 and 6), the program emphasis will obtain the desired agroecological approach to monitoring the status of agroecosystems.

### 4.3. Research Activities on Candidate Indicators and Assessment Endpoints

Because of the desire of the ARG to have an ecological focus, four specific research projects have been selected for inclusion in the 1992 Pilot Project. These projects (see Sections 6.1 - 6.4)

include research on: 1) a response indicator of the biological health of soils based upon the prevalence and frequency of occurrence of specific trophic groups of soil-inhabiting nematodes (Section 6.1); 2) a series of currently available and new habitat indicators (a landscape ecology perspective) to characterize the structure and quality of agricultural landscapes (Section 6.2); 3) a direct comparison of the quality of water available for irrigation and consumption in existing and newly-established wells in agroecosystems with a series of exposure indicators (section 6.3); and, 4) a biomonitor of the impact of ozone on crop production systems (section 6.4). If these research projects confirm the suitability of one or more of the candidate indicators for agroecosystem monitoring, the indicators or measurement endpoints will be included at some level in the 1993 demonstration and pilot projects.

## 4.4. Current Status of the Assessment Endpoints for the Agroecosystem Program

Table 4-3 presents a summary of the current status of the assessment endpoints identified for use and development by the ARG. Expected source measurement/indicator data and sample design for obtaining 1992 Pilot data is indicated, the index period for obtaining measurements is shown, the parties responsible for collecting/handling/summarizing the data are listed, and the stage of development for each assessment endpoint is shown. The definitions of the developmental stages are shown as footnote 2 in the Table.

The flow of the major activities for the 1992 Pilot with emphasis on the assessment endpoints and collection by survey or sampling is shown in Section 8 (Figure 8-1).

**Table 4-3.** Vital statistics on the Assessment Endpoints for the Agroecosystem Program.

| Assessment Endpoint | Source of Data | Sample Design from which data will come | Index Period[1] | Responsible Party | Stage of Development[2] |
|---|---|---|---|---|---|
| Crop Productivity | Survey | Both[3] | Fall | ARG/NASS | 1 |
| Soil Quality: Physical/Chemical | Sampling | Both | Fall | ARG/NASS | 1 |
| Water Quality: Ponds and Existing Wells | Sampling | Hexagon or Rotational | Fall | ARG with Athens-ERL | 1 |
| Land Use / Land Cover | Survey[4] | All of JES | May-June | ARG/NASS | 1 |
| Agrichemical Use | Survey | Both | Fall | ARG/NASS | 1 |
| Soil Biological Health (Nematode indices) | Sampling | Hexagon or Rotational | Fall | ARG/NASS | 2 |
| Landscape Structure | Remote[4] | Off-frame | Several | ARG | 3 |
| Groundwater/Well Comparisons | Sampling | Off-frame | Summer | Athens-ERL | 3 |
| Biological Ozone Indicator (Clones of white clover) | Sampling | Off-frame | Spring/ Summer | ARS cooperators | 3 |
| Socioeconomic Health | Survey | | | | 4 |
| Pest Density | Sampling | | | | 4 |
| Foliar Symptoms | Sampling | | | | 4 |
| Beneficial Insects | Sampling | | | | 4 |
| Genetic Diversity | Survey | | | | 4 |
| Habitat Quality | | | | | 5 |
| Wildlife Populations | | | | | 5 |
| Livestock Productivity | | | | | 5 |
| Nonpoint Source Loading | | | | | 5 |
| Water Quantity (irrigation) | | | | | 5 |
| Other Biomonitor Species | | | | | 5 |

[1] Period during which data is taken (Note: survey data may actually represent earlier events)
[2] 1=developmental 2=research 3=off-frame research 4=under consideration 5=proposed
Numbers 1,2,3 will be included in the 1992 Pilot.
[3] Both=segments from both the hexagon design and the NASS rotational panel
[4] Will also make use of the NASS strata for North Carolina (developed in 1978)

# 5. Description of Specific Assessment Endpoints for The Pilot Project

## 5.1. Crop Productivity

### *5.1.1. Introduction*

When people are concerned about agriculture, crop production is often the focus of their concern -- *Will There Be Enough Food?* was the title of the 1981 Yearbook of Agriculture (USDA 1981). In addition to its crucial importance to human society, the crop plant also provides food for soil microbes, plant-eating insects, and other organisms. Crop productivity is thus an important ecological parameter and an important response indicator of agroecosystem condition.

Figure 5.1-1 illustrates some of the elements which affect crop productivity. Many more anthropogenic factors influence crop plants than influence plants in less highly managed systems. In industrial agriculture, the marketable yield of crop plants is being optimized through management (tillage, planting date, fertilizer, irrigation, etc.), with a view toward economic profit. Mitchell (1984) points out that in monocropping, the economic-agricultural system determines which crop varieties are planted and

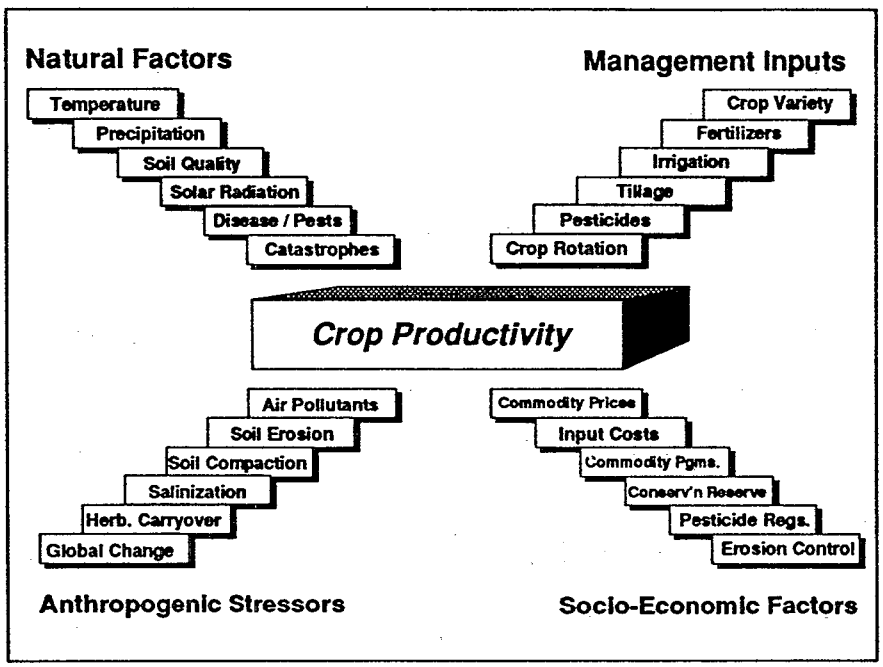


**Figure 5.1-1.** Some factors which influence crop productivity.

what yields are obtained. Crop productivity could be measured in either economic or ecological terms; it is the latter which are of interest in EMAP. An indicator of productivity should be responsive to environmental stresses such as air pollution, climate change, soil degradation and water contamination.

Crop productivity as an assessment endpoint has four facets: total production in a region, yield (production per unit land area), yield as a biological response indicator adjusted for inputs, and production efficiency (production per unit input). Quantifying either of the last two requires a knowledge of inputs as well as yield, but the two perspectives are subtly different. To use yield as a biological response variable, one must adjust for those factors that contributed to yield but are considered extraneous to ecosystem health. These may include natural inputs (e.g. rainfall), human-produced inputs (e.g. pesticides), or both. Production efficiency would quantify agroecosystem status by comparing production achieved to resources expended, whether those resources contributed directly to yield or not. Again the overlap of ecological and socio-economic issues in agroecosystems is apparent. The proposed emphasis for the crop productivity indicators for the 1992 Agroecosystems Pilot is on the third of the four facets of productivity: a biological response that points toward agroecosystem health. Production efficiency will also be considered, especially during the assessment phase.

At a workshop in January 1992 in Athens, Georgia, the ARG endorsed three types of indicators of crop productivity: standardized yield, net primary productivity, and measures derived from remote sensing. These are briefly introduced below.

Crop yields have, of course, been surveyed and reported for decades, but yield alone is not a sufficient indicator of "health". If one field produces a higher yield than another because of additional fertilizer, is that first field therefore "healthier"? Before deciding this it is necessary to account for the effects of management inputs and perhaps for the influence of weather. During the Pilot, several such standardized indicators will be tested, including output/input indices and adjusted yields.

Adjusted or not, crop yield reflects only part of a plant community's productivity. A fuller measure of productivity can be calculated by dividing yield by the harvest index (HI) of that particular crop, to give the total aboveground dry matter. The HI is usually defined as dry matter yield divided by total aboveground dry matter (Tivy 1990, Donald and Hamblin 1976). Given crop yield, HI, and the root-shoot ratio at harvest, an estimate of total dry matter production (i.e., net primary productivity, NPP) can be calculated.

$$NPP = \frac{(harvested\ dry\ matter)}{(harvest\ index)} \left(1 + \frac{roots}{shoot}\right)$$

Alternatively, factors to convert directly from yield to NPP can be constructed from experimental data (Sharp et al. 1976, Klopatek 1978) (See Sections 5.1.3.3 and 5.1.7.3).

Remote sensing is discussed briefly in Section 5.1.9.2, "Possible Alternative Measures of Productivity." The ARG lacks the resources to launch a major effort on this indicator at this time.

A secondary step in the development of indicators of productivity will be to standardize and combine data from different crops. Yields vary among species, even when expressed in common units. The simplest method of combining such data would be to express the yield (or other indicator value) from a sample field as a fraction of the average yield of that crop. The average would be calculated over a reference region and time period. This would partially adjust for the local effects of soils, management practices, and climate while allowing trends to be followed for different crops and locations. A slightly more sophisticated method that adjusts variances as well as means is described in Section 5.1.7.1. Reference means and variances are readily available for yield data, but other productivity indicators may require several years of sampling to establish a baseline.

### *5.1.2. Data to be Collected by NASS*

NASS will gather essential information about both inputs and outputs. They will ask for the production from the harvested area of each sample field (Section 3.3) as well as the units in which these are expressed. For inputs, the Agroecosystem 1992 Pilot Questionnaire will contain questions about timing and amounts of fertilizer, lime, and pesticide applications; about the tillage system; and about irrigation (Appendix 5). For the 1992 Pilot, sample fields will be drawn from the population of planted cropland in North Carolina, to include those crops listed in Table 5.1-1. Crop lands excluded are shown in Table 3-2.

The NASS enumerators will also be collecting soil samples. Data from soil analyses may or may not be used in the process of standardizing yields.

Table 5.1-1. Principal crops eligible for selection in the Agroecosystem 1992 Pilot.

| | |
|---|---|
| Barley | Soybean |
| Corn | Strawberry |
| Hay | Sweet potato |
| Irish Potato | Tobacco |
| Oat | Upland Cotton |
| Peanut | Vegetables |
| Rye | Winter Wheat |
| Sorghum | |

### *5.1.3. Essential Complementary Data*

#### 5.1.3.1. Weather Data

Some productivity indicators should be adjusted for year-to-year weather fluctuations. This will most likely require the use of weather data and some sort of crop growth model.

Geographically referenced weather data will probably be obtained from the National Oceanic and Atmospheric Administration (NOAA) personnel stationed at the EPA laboratory in Research Triangle Park, NC. An initial list of needed data was discussed with Sharon LeDuc, Ellen Cooter, and Brian Eder of (NOAA) in late November 1991. We anticipate that daily precipitation totals and daily high and low temperatures will be needed. Some measure of insolation or photosynthetically active radiation (PAR) on a daily basis and a database containing drought index values, should also be obtained. A final list of weather data needs will be compiled following consultation with several crop growth modelers and after selection of models to be used.

#### 5.1.3.2. Production Practices Not Queried

Certain values needed for calculations will not be asked on the Survey Questionnaire or will not be known by some farmers, so the values must be obtained from other sources. For example, industry standards for moisture content of the major U.S. crops will be obtained from NASS. Crop models may also require parameters such as plant density (number of plants per unit area). Typical values of such factors will be obtained from the literature or from the Cooperative Extension Service personnel.

#### 5.1.3.3. Conversion Factors

The most difficult complementary data to obtain will be the conversion factors for standardizing inputs and outputs. Two issues must be addressed: 1) conversion factor availability for a given crop or input and 2) variability of the conversion factor. If energy productivity is calculated, conversions of input values to energy units will come from the literature (e.g., Southwell and Rothwell 1977, Fluck and Baird 1980, Stout 1990). Factors for calculating NPP present several challenges. The HI and root-shoot ratios can be used to calculate primary productivity from harvested yield, but these ratios depend on variables such as fertility, crop variety, water status, and ozone stress (Donald and Hamblin 1976, Pettersson 1987, Temple 1990). For the Pilot, conversion factors used by Sharp et al. (1976) for eleven crops will be the

starting point (Table 5.1-2). These factors allow conversion from yield to productivity. Standard moisture contents will be obtained from NASS, rather than assuming 12% for every crop, as Sharp et al. has done. Using these conversion factors means accepting that they have not been validated, as well as assuming that they have not changed in 20 years. It would be impractical for the ARG to try to derive conversion factors empirically, so further research into the literature is planned to find conversion factors and their variability. The search initially may be restricted to six to eight major crops. There are many unanswered questions: Are there different conversion factors for different locations or soil types? How is below-ground productivity included? Can conversion factors derived at one location be applied to a larger region? Can crop growth models be used to verify conversion factors?

Table 5.1-2. Conversion factors from yield to net primary productivity (NPP).[1/]

| Crop | Conversion Factor |
|---|---|
| Wheat | 3.69 |
| Soybean | 4.52 |
| Corn | 2.62 |
| Oats: winter<br>spring | 5.30<br>5.22 |
| Irish and sweet potatoes | 2.47 |
| Cotton (lint yield) | 2.08 |
| Tobacco | 2.03 |
| Peanuts | 2.00 |
| Hay | 1.30 |

[1/] Source: Sharp et al. 1976. Yields are first expressed in tons/ha, then multiplied by the given factors, and then adjusted to 0% moisture to give NPP in tons/ha. Values for wheat, corn, oats, and tobacco had been calculated from North Carolina data.

#### 5.1.3.4. Reference Yield Values

For purposes of calculating normalized yield, county average yields for the reference period of 1980-1989 will be used (see Section 5.1.7.1). These have been obtained from NASS for the major crops in North Carolina.

#### 5.1.3.5. Soil Type

Some models may require more detailed information about the soil than the data which the ARG will be obtaining from each field. Procedures are being developed to determine the soil series at each sample site. This will allow access to information from the State Soil Survey Database (SSSD).

### *5.1.4. Logistics*

The field-level data needed for the crop productivity indicators will be taken from the Agroecosystem Survey Questionnaire to be administered by NASS in the fall of 1992 (Appendix 5). Logistics for obtaining soil samples are described in Section 5.2. As mentioned above, some soils data will be derived from the SSSD, which the ARG is obtaining. Complementary data from the literature and other sources will be obtained by the ARG. Weather and climate databases will be obtained through the ARG information manager, the EMAP Information Management Committee, and possibly NOAA cooperators.

### *5.1.5. Quality Assurance*

Quality Assurance (QA) procedures for data collected by NASS are discussed in Section 7. For weather data, QA procedures will be discussed with the supplier of the database. It is anticipated that the complementary data will present several QA problems. For example, the factors from Sharp et al. (1976) do not carry associated estimates of variability. Procedures will be investigated for developing QA standards for conversion factors. QA for indicators derived

using crop growth models will also require development. In particular, Data Quality Objectives (DQOs) will not be estimated until after the Pilot is completed.

### *5.1.6. Metadata Requirements*

Because data from so many sources will be needed, metadata requirements will be extensive. They will fall into different groups, depending on their level of applicability (Table 5.1-3). The QA/QC procedures will be part of the metadata.

5.1.6.1. Data keys will be needed to identify (ID) the sample: date (year), frame (hexagon or NASS), PSU/segment ID and sample (field) number. Although the association of the sample number with a particular field must be kept confidential, some geographic information will be needed. In particular, the name of the county will be needed so that county averages can be used to normalize yields. It may also be necessary to indicate the region to which the field belongs, if summary statistics are calculated for subregions of the state, although it may be possible to use the PSU identifier for assigning fields to regions.

5.1.6.2. Certain metadata items will be the same for each record in the entire database. These include the descriptions of each variable. In many cases the description will be the question which was asked in the questionnaire. The description is to include the units in which the quantity is expressed, for example "acres" for the area of a field or area under irrigation, "dollars per gallon" for the price of fuel, and "acre-inches" for the amount of irrigation water. Currently, NASS data are taken in U.S. units. Some quantities, such as moisture content and fertilizer analysis, will be dimensionless ratios and should be expressed as decimals (not percentages). The description of fertilizer analysis should indicate the chemical form in which the analysis is expressed, e.g. P vs. $P_2O_5$. A few conversion factors will apply to the entire database, for example the conversion from acres to hectares. All final summary statistics will be expressed in metric units or as dimensionless ratios.

Table 5.1-3. Elements of metadata to be recorded in association with data for the crop productivity indicators, not including ancillary data such as weather.

1. Data keys
   - Year
   - Frame (hexagon or NASS)
   - PSU/segment ID
   - Sample (field) number
2. Elements which apply to every record in the database
   - Description of variable (including the form in which chemical species are expressed, such as P vs. $P_2O_5$)
   - Units (may be dimensionless)
   - Coding tables for pesticide product codes, etc.
3. Elements which are associated with a particular crop, land use or input
   - Units for crop yield (bu., tons, etc.)
   - Conversion factors from yield to NPP, including units
   - Conversion factors from inputs to energy (if used)
   - Source of conversion factors
   - Variability of conversion factors
   - Common names for pesticides
4. Elements associated with individual records (these elements vary among or within sampled fields)
   - Units for fertilizer, manure, and pesticides
   - Units, source and base period for county averages used to standardize yields

Another category of metadata which will be the same for the entire database will be the translation tables for those variables that are recorded by code numbers (unless NASS converts them to text before shipping to the ARG): crop and land use codes; fertilizer timing and application method; pesticide product code, timing, application method, and applicator; type of manure; tillage system; erosion control methods; irrigation system; and source of irrigation water. If yes and no responses are stored as 1's and 0's, this needs to be documented.

5.1.6.3. Some of the metadata will be associated with a particular crop, land use, or input. For example, yields are expressed in different units for different crops, and different crops have different factors for converting yield to NPP. The descriptions of the conversion factor variables

will need to reveal the quantity to which they apply and what units are being changed to what other units. The origin of the conversion factors should be recorded, including the source from which they were obtained, an estimate of their variability, and the mathematical derivation of composite conversion factors. If production inputs are to be standardized, the conversion factors (e.g. for expressing fuel in energy units, manure as nutrient equivalent, etc.) will likewise need extensive documentation.

5.1.6.4. A fourth group of metadata needs to be associated with individual records in the dataset, because there may be differences among or within fields. This group includes the units for fertilizer, manure, and pesticides. Care must be taken that the correct conversion factors are applied to these quantities, because units will vary. Another group of data at this level will be the units, source and years of the county averages used for standardizing yields. These need not be stored with the individual record, but must be indexed by the particular county and crop.

### *5.1.7. Data Analysis and Integration*

Figure 5.1-2 shows the 1990 harvested acreage for 28 North Carolina crops. Except for apples, peaches and blueberries, any of these crops would be eligible to be sampled in the fall of 1992. However, many occupy such small areas that they will be missed. Sample fields will be drawn according to the protocol outlined in Section 3. Except for NPP, indicator values will be calculated separately for each crop, so that shifts in the productivity of one crop do not mask shifts in the productivity of others. Keeping the indicators separate is also a way of recognizing the important differences among the requirements and adaptation of different crop plants.

It may be impossible to calculate some or all of the productivity indicators for certain crops. For example, the sampling scheme might draw too few rye fields for a reliable estimate, or existing crop growth models may be inadequate for calculating adjusted yields of sweetpotatoes. It is not known how often these problems will occur, but it is unlikely that indicators will be reported for all of the crops found on the sample fields (Table 5.1-1).

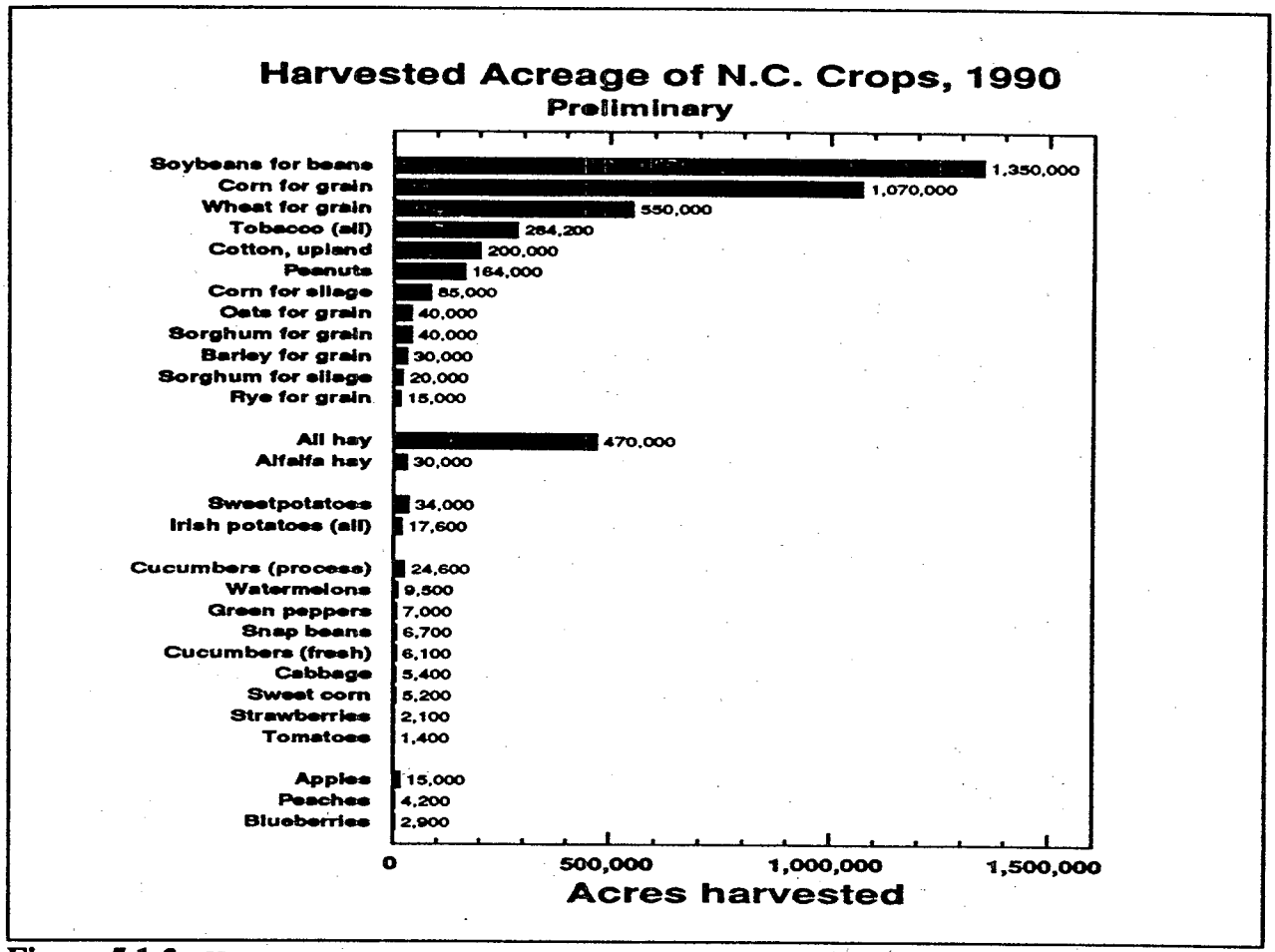


**Figure 5.1-2.** Harvested acreage of several North Carolina crops, 1990 (preliminary). Source: 1991 North Carolina Agricultural Statistics.

Efforts will focus on calculating indicators separately for each crop, but attempts will also be made to combine data from different crops into some sort of overall index. It may be possible to weight and then directly combine individual values if they are on a common scale (as NPP will be). If indicators such as adjusted yield are not on a common scale, the combined index may need to wait until the ARG has established baseline indicator values for each crop. These baselines can then be used for standardization and for detecting trends. "Normalized yield", as described below, will be a test of this sort of calculation.

The five types of indicators proposed here range from the simple and straightforward to the complex and uncertain, but potentially more useful. Simple yield is a key building block of the

other indicators. Normalized yield is an easy way to try to combine data across crops. The net primary productivity indicator will use data from all crops to make a broad ecological statement. Output/input relationships and adjusted yield are expected to unmask inherent productivity differences hidden by management or other variables.

#### 5.1.7.1. Simple yield

Straightforward yield figures are routinely reported by agencies such as NASS. Nevertheless, there are four reasons for the ARG to report simple agronomic yields:

- The values obtained can be compared to the estimates which NASS gets from a much larger sample.

- Simple yields form the foundation for the adjusted yields. It will be interesting to see the spatial distributions and cdf's of such yields before adjustment.

- A simple assessment can be done by plotting yields over time and comparing them to changes in inputs over time. This may not be the most powerful use of the data, though, since inputs and output will be known on a field-by-field basis.

- The method of aggregating over sub-regions within the state can be tested with simple yield. Data from NASS are not aggregated this way; the approach may be unique to EMAP.

#### 5.1.7.2. Normalized yield

Normalized yield (Y') will be calculated for each field by using that field's yield per acre (Y = production from field/area harvested), the county average for the arbitrary reference period 1980-1989 ($Y_{ref}$), and the standard deviation of that average yield ($s$). Similar to a standard normal variate, the calculation will be

$$Y' = \frac{Y - Y_{ref}}{s} + 5$$

The number 5 is added arbitrarily so that the distribution of Y′ will have a mean of 5. Because the standard deviation of Y′ is 1 and its mean is 5, negative values will be conveniently rare. The advantage of this method of standardization is that both means and variances of different crops are put on a similar scale. For simplicity, *s* will be calculated from temporal (year-to-year) variation in the county means. Values of Y′ will be averaged over the fields within each segment and weighted according to the inclusion probabilities of the field being sampled. Segment means will be used to calculate regional means, quartiles, etc., with weighting and stratification as appropriate (see Section 3).

5.1.7.3. Net Primary Productivity

Net primary productivity (NPP) is the net accumulation of plant biomass per unit area per unit time. It is a useful ecological indicator because it allows comparisons among different types of ecosystems. An estimate of seasonal NPP will be calculated from the Pilot yield data. The yield of each crop will be expressed in kg/ha, and then converted from economic yield to dry matter production, using conversion factors like those from Sharp et al. 1976 (Table 5.1-2), along with standard moisture contents. A sample calculation is given in Section 5.1.7.6, though the method of aggregation and the method of handling double crops have yet to be determined. Net primary productivity will not be reported for individual crops, since it is simply a multiple of the yield. Also, NPP will not be compared across crops, because different species would be expected to have different NPPs. Instead, NPP will be aggregated over all sampled crops within a region. The method of integrating these values over each region of interest will need to account for the area occupied by each crop. It would seem that regional productivity will be a function of both the productivity of individual fields and the patterns of land use (Sharp et al. 1976; Turner 1987).

### 5.1.7.4. Output/Input Relationships

One way of measuring plant health using ARG data is to look at the response of yield or NPP to various inputs, either singly or collectively. This might involve single-factor or multi-factor productivity indices. Another possibility would be to use Agroecosystem data to determine the coefficients relating yield to inputs (see for example Lin et al. 1991).

Within the concept of a multi-factor index, one approach to aggregating the input data would be to put them on a common energy scale. Ideally, this should be done using process analysis and on the basis of energy resource depletion (Southwell and Rothwell 1977) or some similar philosophy. Various types of energy output/input ratios have been used in agriculture (Fluck and Baird 1980); however, the validity of the energy ratio (energy output per energy input) has been questioned, and energy productivity (e.g., kg of production per unit of input energy) has been suggested as a better measure (Fluck 1979).

### 5.1.7.5. Adjusted Yield

Another way to develop an indicator of crop health in agroecosystems would be to estimate what the yield on each field would have been if a standard set of inputs had been used. These adjusted values can then be aggregated, mapped, or treated in other ways. Such adjustments would come from existing research findings on the response of yield to inputs. A similar method would be to build an indicator from a difference or ratio between a field's yield and the yield predicted by a statistical or process model. Much work needs to be done in this area. The two critical steps are (1) deciding which inputs, natural and anthropogenic, should be accounted for and (2) finding the means to make those adjustments. Whether indicators should be adjusted for fluctuations in the weather is a major question. Such an adjustment may stabilize the variability inherent in yield data, but if all weather variations were accounted for, it might be more difficult to detect changes caused by global climate change (except through shifts in land use).

Rather than using the predicted yield from a model, an adjustment could be made using an estimate of the optimum yield for a given crop on a given soil series. Such values are published by the USDA Soil Conservation Service for the six or eight major crops in each soil survey, but these are not updated very often, and the updates occur at staggered intervals (USDA Soil Conservation Service 1970, 1983). If this approach is to be useful, a set of estimates would be needed that were made within a few years of each other and covering the entire state (eventually the country).

### 5.1.7.6. Sample Calculations

Following are examples of how two of the indicators would be calculated, given the following hypothetical yields for 1992.

Hypothetical corn yield in sample field: 80 bu/A @ 12.5% moisture

Hypothetical soybean yield in sample field: 26 bu/A @ 8.5% moisture

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Sample calculation: *normalized yield* (Section 5.1.7.2)

Assume mean yields and standard deviations in County A for the reference period 1980-1989:

Corn: mean = 71 bu/A, std. dev. = 20 bu/A

Soybean: mean = 25 bu/A, std. dev. = 7 bu/A

Normalized yields

$$Y' = \frac{Y - Y_{ref}}{S} + 5$$

Corn: (80 - 71)/20 + 5 = 5.45

Soybean: (26-25)/7 + 5 = 5.14

These will be calculated for each field.

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Sample calculation: *net primary productivity* (Section 5.1.7.3)

NPP = yield*(unit conversion to tons/ha)*(NPP conversion factor)*(1-fraction moisture)

- Unit conversion factors from standard bushel weights for corn (56lb) and soybeans (60lb)
- NPP conversion factors from Sharp et al. 1976, see Table 5.1-2

Corn

$$(80\frac{bu}{A})(0.0628\frac{ton}{ha}/\frac{bu}{A})(2.62\frac{NPP}{yield})(1.00-0.125)$$

$$=11.5\frac{tons}{ha}$$

Soybean

$$(26\frac{bu}{A})(0.0672\frac{tons}{ha}/\frac{bu}{A})(4.52\frac{NPP}{yield})(1.00-0.085)$$

$$=7.23\frac{tons}{ha}$$

In practice, NPP might be calculated by starting with the production of each crop over the entire region, which can be converted to net primary *production*, summed over crops, and divided by the total harvested area to give the regional NPP estimate.

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### *5.1.8. Interpretation of Indicators*

The above indicators will serve as biological response variables that show whether productivity is rising, falling, or remaining the same over time. The goal of the ARG is to measure the status of productivity indicators, along with other agroecosystem indicators, to obtain a picture of the condition of U.S. agricultural resources with regard to sustaining both the supply of agricultural commodities and the ecological integrity of the system. Because of the great differences among crop species, most indicators will be interpreted separately for each crop before a composite index for all crops is calculated. The exception will be NPP, which will only be reported as a composite.

Assigning value judgements to an indicator (good status vs. bad status) can only be done in reference to some criterion. Unfortunately, such criteria for crop productivity are hard to come by, with the possible exception of optimum yields published in soil surveys or perhaps yield contests or the outputs of crop models. Thus, the main use of productivity indicators will be for following trends. It may be difficult to detect trends, and innovative ways must be developed to distinguish the effects of changes in the natural resource base from other effects. Complicating factors include shifts in production decisions caused by price shifts and changes in government programs (W.E. Foster, NCSU, personal communication). The easiest way to try to interpret the data will be to look at the graph of simple yields or NPP over time alongside the graphs of various inputs such as fertilizer and land use. The more complex indicators will then be examined. These will be designed to be less sensitive to extraneous factors.

A secondary type of assessment will be to look for associations among indicators and for associations between indicators and the forces that may drive them. Spatial maps of the crop indicators can be used to overlay the maps of other agroecosystem indicators and other data. For example, maps for yield could be used to overlay maps of soil quality or insolation. This technique can serve the ARG's primary goal (i.e., using multiple indicators to get a picture of agroecosystem condition in various regions) and it might also be used to generate hypotheses for why certain indicators are responding as they are. Similarly, trends in each response indicator

over time can be compared with trends in other response indicators and trends in stressor indicators (including inputs). This may preserve some of the information that is lost when indicators are adjusted for other factors.

Particular care is needed when interpreting normalized yield (Section 5.1.7.2). Because each value is relative to a county average, most spatial (county-to-county) variability will have been removed. The normalized yield will show whether a particular region is producing above, below, or at about the same level as it did during the reference period. Because yields vary widely from year to year, it will take some time to determine if such differences are true trends. The calculation of normalized yield does nothing to account for changes in technology, climate, or cropping pattern, so such factors will be reflected in the trends that are found. Despite these concerns, this indicator will be a test of one method of combining data across crops. Historic yield data allow this to be done in the Pilot, while standardization of other indicators may need to wait until baselines have been established.

An output table (such as Table 5.1-4) will be generated for each indicator, as will a graph of the cumulative distribution function (example not shown), and a map of indicator values. For examples of output tables, cdf's, and other ways of presenting data, see Section 3 and Meyer et al. 1990. Because NPP will include data from all crops within a summary region, cdfs will not be meaningful. Instead, population estimates of the mean and variance for each region will be reported.

### *5.1.9. Research Goals and Applications*

#### 5.1.9.1. Continuing Research on the Indicators of Crop Productivity

As mentioned above, extensive research is required before adjusted yield, output/input indices, and NPP become useful indicators. Statistical and process models must be examined. More yield-to-NPP conversion factors must be found for different crops (possibly for cultivars within crops), and the variability of those conversion factors must be determined. Improvements

in breeding can alter the harvest index (i.e., Turner 1987) so these may need to be updated over time. The inclusion of an estimate of root production is desirable, and the conversion factors from Sharp et al. (1976) attempt to do this, but root production is likely to be underestimated because of sampling error (Mitchell 1984) and because root exudates and "slough-off" might not be included (Coleman et al. 1976). Also, stresses on the crop (e.g., drought, air pollution) will affect the root-shoot ratio. If energy is to be used as a common currency for inputs, then conversion factors must be found. The energy equivalents of different production inputs will change as industries try to be more energy-efficient; however, the factors reported by Southwell and Rothwell (1977) should still be valid (Terry Rothwell, A+E Engineering, personal communication). As new technologies are adopted, especially new pesticides, their energy content must be determined. Trying to keep up with such changes may be prohibitively time-consuming.

One limitation of the Pilot statistical design is the small sample size. Ways of using a larger NASS sample for indicator calculations will be investigated. Of course when associations with other indicators are tested, only the values from the Pilot sample can be used. It is not yet known what the summary regions will be, other than the entire state of North Carolina. It is also undecided what region should serve as the basis for means and standard deviations used in normalizing the various indicators. Counties will serve this purpose for the normalized yield indicator in the Pilot, but there may never be enough data to do county-by-county standardization of other indicators. Therefore, larger regions should be tested for normalizing yield in the Pilot. Regions should be chosen so as to reduce the variability of the normalized indicator.

The applicability of measures of yield and crop productivity indicators for the future must be addressed. When the Agroecosystem Program expands to include pastures, orchards and livestock, and adjoining lands, what changes will be needed?

The suitability of the Survey Questionnaire will be evaluated after the pilot (i.e., should seeding rate be asked). Can some questions be dropped? It is important that enough data be gathered to allow calculation of a wide range of indices according to the developing interests of the ARG and the interests of future researchers.

Table 5.1-4. Example output table for an indicator of crop productivity

| | Average Normalized Yield in Regions of North Carolina [1] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crop[2] | Coastal Plain | | | | | Piedmont | | | | | Mountains | | | | |
| | mean | 1st quartile | median | 3rd q'tile | N | mean | 1st quartile | median | 3rd q'tile | N | mean | 1st quartile | median | 3rd q'tile | N |
| Soybeans | | | | | | | | | | | | | | | |
| Corn (grain) | | | | | | | | | | | | | | | |
| Wheat (grain) | | | | | | | | | | | | | | | |
| Tobacco (all) | | | | | | | | | | | | | | | |
| Cotton | | | | | | | | | | | | | | | |
| Peanuts | | | | | | | | | | | | | | | |
| Corn (silage) | | | | | | | | | | | | | | | |
| Oats (grain) | | | | | | | | | | | | | | | |
| Sorghum (grain) | | | | | | | | | | | | | | | |
| Barley (grain) | | | | | | | | | | | | | | | |
| Sorghum (silage) | | | | | | | | | | | | | | | |
| Rye (grain) | | | | | | | | | | | | | | | |
| Hay (all) | | | | | | | | | | | | | | | |
| Sweetpotatoes | | | | | | | | | | | | | | | |
| Irish potatoes | | | | | | | | | | | | | | | |
| Composite Index For All Crops | | | | | | | | | | | | | | | |

[1] Regions shown are for illustration only. Actual summary regions have yet to be determined.
[2] It may not be possible to calculate all indicators for all crops. See Section 5.1.7.
Note: Pastures, idle land, and woody perennials will not be included in the 1992 pilot.

### 5.1.9.2. Possible Alternative Measures of Productivity

Some of the above indicators may be unreliable because they depend on ancillary information of unknown quality. It would be helpful to have a more straightforward indicator of productivity. The use of remotely sensed data must be considered, along with some method of ground truthing, possibly using micrometeorological techniques for calculating carbon flux (Tim Ball, Desert Research Institute, personal communication). Again, this could be a common indicator across terrestrial ecosystems. Note that weed productivity would be included in such a measurement, but not in the currently proposed indicators. The following paragraphs summarize the report of the workgroup which discussed remote sensing at the January 1992 Agroecosystems crop productivity workshop.

Indicators computed from remotely sensed data could integrate plant productivity at a landscape scale and would complement indicators of crop productivity currently planned at the field level. Remotely sensed vegetation indices could provide a measure of plant productivity at the full agroecosystem scale, including both crop and noncrop plants. Productivity of idle land, Conservation Reserve Program (CRP) land, and adjacent noncrop areas, all considered part of the agroecosystem, could be measured.

Indicators that can be derived from remotely sensed data include (1) vegetation indices such as the Normalized Difference Vegetation Index (NDVI) or "greenness index", (2) actual transpiration, (3) $CO_2$ flux and (4) leaf area index (LAI) (Wiegand et al. 1991, Box et al. 1989). The group decided to focus on the possibility of data from the Advanced Very High Resolution Radiometer (AVHRR) for the following reasons: (1) frequent collection (twice daily), (2) historical record of over ten years, (3) inexpensive purchase cost and (4) known to address net primary productivity (Box et al. 1989). The EMAP Integration and Assessment team is in the process of obtaining 1990 and 1991 AVHRR data for all of the U.S.

The greenness index can be calculated from AVHRR data and is responsive to many kinds of plant stress. In an associative, diagnostic study, the indicator could be used in combination

with other data such as land use, ozone, drought, and disease epidemics, that are readily available at the appropriate scale. Ancillary data useful for associative studies are also available from remote sensing. These include weather variables, soil temperature and moisture, water stress index and solar radiation.

A vegetation index could be explored in a pilot project by obtaining the AVHRR pixels for the NASS PSUs used in the 1992 Agroecosystem Pilot. AVHRR pixels are about 1.1 $km^2$. The greenness index is best calculated with three to five pixels for each location (about 5x5 km resolution). About 35 AVHRR pixels would be needed to cover a 6-8 $mi^2$ PSU. The PSU, rather than the segment, would probably be the most appropriate scale for this indicator, but this needs to be explored further. The use of Thematic Mapper (TM) data, rather than AVHRR data, could also be evaluated. After the PSUs were identified, the AVHRR (and/or TM) data for the past ten years would be obtained and the greenness index (GI) for each PSU calculated for each year. This value could be used as a baseline for evaluating the GI for 1992. The index would not be normalized with respect to management (e.g. fertilizer inputs). These management factors would be considered a part of the variability.

## 5.2. Soil Quality: Physical and Chemical Components

### *5.2.1. Introduction*

About 13,100 kinds of soils have been recognized in the U.S.; more than twice as many kinds of map unit deliniations exist when slope, erosion, rocky, and stony phases are considered (McCracken et al. 1985). Soils can be thought of as "archives" of the long-term interactions among the major soil-forming factors of climate, parent material, plant material and topography, and are organized and structured natural entities in their own right.

Soils function as sinks and sources of biogeochemical elements, as filters for pollutants, and as an environment for growth and development of plants and other biological communities. They are liable to change, gradually or abruptly and partly irreversibly, due to human use. Soil structure is especially sensitive to human activities (Kay 1989). The main activities affecting soils in agroecosystems are vehicular traffic, tillage, use of agricultural chemicals, waste disposal and land use. In response to the perceived need 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 organic amendments are now 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 focus of soil quality assessment in agroecosystems will be on the presence, extent and change in those soil properties that are (1) important to the functioning of the soil system, (2) known to be affected by agricultural land management, and (3) can be adequately measured in one sampling period at a regional scale. The physical and chemical indicators of soil quality to be measured in the pilot are defined in Table 5.2-1. Biological indicators would also be valuable indicators of soil response to management; research on nematode trophic groups as a biological indicator of soil quality is discussed in Section 6.1.

Table 5.2-1. Description of physical and chemical soil quality indicators.

| SUMMARY STATISTIC<br>*Single measures* | DESCRIPTION |
|---|---|
| Organic carbon | Quantity of organic carbon in first 20 cm of soil (plow layer) |
| Clay content | % clay in plow layer |
| Available water capacity | Water retention between -33 and -1500 kPa |
| Porosity | Water retension at -5 kPa and -10 kPa |
| Soil pH | Measure of soil acidity and nutrient availability |
| Base saturation | Extent to which the soil exchange capacity is occupied by base cations |
| Exchangeable acidity (humid regions) | Extent to which the exchange capacity is occupied by H and Al |
| Exchangeable sodium percentage (arid regions) | Extent to which the exchange capacity is occupied by Na |
| Electrical conductivity | Measure of salt concentration in soil water |
| Extractable aluminum (humid regions) | Quantity of aluminum in the plow layer |
| Mercury | Quantity of mercury in the plow layer |
| Bulk density (intact core)[1/] | Mass of dry soil per unit volume |
| Hydraulic conductivity (intact core)[1/] | Rate at which soils transmits water while saturated |

[1/] will not be included in initial pilot but will be included in subsequent pilots as sampling protocol for intact cores is completed

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 indicators and to begin evaluation of how well the chosen measurements and derived indices will reflect changing conditions. Because standards of soil quality will vary with climate and soil, determination the *rate of change* of soil quality will be an important long-term objective. A second long-term objective is 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 structure, tilth, fertility, contamination, and productivity (Table 5.2-2). Thirdly, soil quality information will be combined with other pilot data into a picture of over-all agroecosystem health. A fourth long-term objective is to integrate information on the health of agricultural soils in the U.S. with information on soils in forests and arid lands to provide an overall picture of soil quality across terrestrial ecosystems.

### *5.2.2. Data Sources*

Data for soil quality assessment in the pilot will come from soil samples taken by National Agricultural Statistics Service (NASS) enumerators. Data will also be obained from the Soil Conservation Service (SCS) State Soil Survey Database (SSSD) and Natural Resources Inventory (NRI).

The State Soil Survey Database (SSSD) databases are currently being compiled at a state level by linking the information from the Soil Interpretations Record Data Base (commonly known as the Soils-5 database), with the specific map unit identified in the county-level soil surveys (compiled in the Soils-6 database). The SSSD is, therefore, a more refined and accurate source of information about a specific soil than the Soils-5 database because the information is linked to a specific geographic location (SCS National Soil Survey Lab, Lincoln, NE, personal communication, 1991).

Table 5.2-2. Research indices of soil quality.

| Assessment or index | Measurements |
|---|---|
| Contamination/Toxins | Lead/cadmium/mercury |
| Anthropogenic | and other trace metal contaminants |
| Nonanthropogenic | pH |
| acidification | Exchangeable sodium percentage |
| salinization | Base saturation |
| alkalinization | Exchangeable acidity |
| | Extractable Al |
| | Electrical conductivity |
| | Organic carbon |
| Soil structure | Bulk density |
| (tilth, porosity) | Available water capacity |
| | Porosity |
| | Organic carbon |
| | % clay |
| Soil fertility | Base saturation |
| | Extractable P |
| | Organic matter |
| | pH |
| | Exchangeable acidity |
| Leaching Potential/ | Slope |
| Adsorption Potential/ | Infiltration (Hydrologic group) |
| Run-off Potential | Horizon depth |
| (SCS ratings) | Organic matter |
| | K factor |
| Sensitivity to | Texture |
| degradation from | Drainage |
| intensive agriculture | Erosion rate |
| | Erodibility index (R*K*L*S/T) |
| | Soil depth |
| | Rooting depth |
| | Depth to water table |
| | Restrictive soil layers |
| | Landscape position (hillslope) |
| | taxonomic order or suborder |
| Erosion | 'Highly Erodible Land' rating-water |
| | 'Highly Erodible Land' rating-wind |
| | Erosion rate (USLE) |
| | Erosion index (USLE/T) |
| Productivity | Soil properties such as bulk density, OM and pH |

Selected data elements from the SSSD to be used in the pilot are listed in Table 5.2-3. Useful data elements from this database include grouping variables, such as taxonomic classification, Major Land Resource Area, and soil depth, to be used in statistical analyses. The database also contains data on soil physical properties, such as bulk density, which will not be measured directly in the first pilot until sampling protocols for intact soil cores are completed. The SSSD data will be linked to Agroecosystem data by identifying the map unit of the sample point on NASS aerial photos and the appropriate SCS county soil map, and requesting the selected data elements for each mapping unit from the state SCS office. Possible collaboration, in the office and/or in the field, with SCS personnel is being explored to help identify the soil mapping unit.

SSSD data can also be used to determine expected ranges in each state of many soil properties, including pH, bulk density, available water capacity, organic matter, permeability and clay. The Agroecosystem Resource Group (ARG) is in the process of acquiring data from the North Carolina Soil Conservation Service Office for this purpose.

### *5.2.3. Indicators*

The initial set of physical and chemical indicators of soil quality to be measured in the Pilot are described in some detail below. 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 measureable in a single sampling period on a regional basis. Many are key variables in soil productivity models. Methodologies for sample collection and laboratory analyses are described in Section 5.2.4.

Approaches to data analysis and application are discussed in Section 5.2.7 and 5.2.8. Generally, ranges and within- and among-site variance will be determined for each measurement to help refine sampling design and to determine what magnitude of change could likely be measured over time at a regional scale. Secondly, the data will be used to begin an evaluation of how well the indicators, and derived indices, would truly reflect good, poor, or changing conditions. Although identified ranges for indicators and benchmark references of soil quality

Table 5.2-3. Requested data elements from the SCS State Soil Survey Database

| Data element | Definition |
|---|---|
| MLRA | code for Major Land Resource Area |
| survey area ID | code for state+FIPS (state soil survey area) |
| map unit ID | stssaid+musym: uniquely identifies a mapunit within a state |
| map unit symbol | map unit symbol |
| map unit name | map unit name |
| class code | code for taxonomic classification of the soil |
| soil layer | identifies the original layers on the Soils-5 record |
| soil layer | depth to the lower boundary of the soil layer (inches) |
| soil layer | depth to the upper boundary of the soil layer (inches) |
| available water capacity | maximum value for the range of awc (inches/in) |
| available water capacity | minimum value for the range in awc (inches/in) |
| bulk density | maximum value for the range in moist bulk density (g/cm3) |
| bulk density | minimum value for the range in moist bulk density (g/cm3) |
| cation exchange capacity | maximum value for the range in CEC |
| cation exchange capacity | minimum value for the range in CEC |
| clay | maximum value for the clay content (% in less than 2 mm fraction) |
| clay | minimum value for the clay content (% in less than 2 mm fraction) |
| organic matter | maximum value for the range in OM (% by weight) |
| organic matter | minimum value for the range in OM (% by weight) |
| permeability | maximum value for the range in permeability (inches/hour) |
| permeability | minimum value for the range in permeability (inches/hour) |
| pH | maximum value for the range in pH |
| pH | minimum value for the range in pH |
| K factor | erodibility factor; can be used in USLE (tons/acre) |
| T factor | soil loss tolerance factor; can be used to interpret USLE (tons/acre) |
| SCS LCC | SCS Land Capability Class rating (nonirrigated) |
| SCS LCC | SCS Land Capability Class- subclass rating |
| slope | maximum value for the range of slope within a mapunit (%) |
| slope | minimum value for the range of slope within a mapunit (%) |
| hydrologic group | the SCS hydrologic group |
| drainage | code identifying the natural drainage condition/frq+duration when saturation-free |
| prime farmland | SCS prime farmland classification |
| depth | depth to water table |
| | depth to bedrock |

are generally lacking, soil quality standards and ratings are of great interest to SCS and other soil scientists, who are making good progress with respect to specific soil uses or functions (see Table 5.2-17) and it is likely that this will continue to be an active area of research that can be applied in the EMAP program. Evaluation of soil quality indicators is made even more complex by the fact that what is a good or poor indicator range or value will vary with climate, soil and management scenarios. General, baseline reference points with which to group soils and sampling sites for indicator evaluation are needed, and different approaches to this will be explored in this and subsequent pilots (see Section 5.2.7).

#### 5.2.3.1. Organic carbon

The organic matter content of surface soils range from 0.1% in mineral soils to nearly 100% in organic soils (Schnitzer 1982). 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 sandy soils, and supplies nutrients for plants and microorganisms.

Carbon is the main element present in soil organic matter, comprising from 48 to 58% of total weight (Nelson and Sommers 1982). Organic carbon (C) will be used initially as a measure of soil organic matter because 1) soil organic matter is difficult to estimate quantitatively (Nelson and Sommers 1982) and 2) different organic matter fractions considered important to nutrient cycling, structure and biological activity in soils require different extraction and analysis procedures (Schnitzer 1982, Stevenson and Elliot 1985).

A large amount of data exists on changes in organic C when forests and grasslands were converted into agricultural land. Mann (1986) confirmed several previous reports that the greatest rates of change occurred in most soils in the first 20 years after conversion. Soils very low in C tended to gain small amounts after cultivation; soils high in C lost at least 20% in the top 30 cm during cultivation. After the initial rapid loss of C after land conversion, rate of C loss in cultivated soils tends to slow and approach a new equilibrium (Mann 1986). 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 C is lost due to soil erosion, often accompanied by a loss in nutrients, deterioration of soil structure and diminished soil workability (Pierce et al. 1991, Frye et al. 1982). Depletion of soil organic matter and erosion are spirally cyclic because a decrease in organic matter increases the susceptibility of a soil to erosion (Pierce et al. 1991). Changes in land management, such as the increasing implementation of no-till practices, may affect rates of organic C loss (Coleman et al. 1990).

Burke et al. (1989) developed predictive models of organic C loss in U.S. grasslands using climate, soil texture, landscape position and management practices as driving variables. These models help to identify areas which are most vulnerable to organic C loss. An "ideal" or "healthy" standard of organic C in soils does not exist because it depends on soil-forming processes of each soil. The goal of the Agroecosystem Program is to provide a broad-scale, long-term picture of organic C in agricultural soils. A decline in organic C would be interpreted as a warning of decline in soil quality.

#### 5.2.3.2 Clay content

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 subsurface soil layers are increasingly incorporated into the plow layer (Indorante et al. 1991, Frye et al. 1982, Stone et al. 1985, Pierce et al. 1991). This is due to selective removal of fine particles during the erosion process, and to mixing of subsoil into the surface layer. 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 et al. 1991).

As in the case of organic C, an "ideal" or "healthy" standard of clay content in soil does not exist. The indicator is intended to provide a broad-scale, long-term picture of clay content in the top 20 cm of agricultural soils. An increase in clay content would be interpreted as an indicator of soil loss and a warning of decline in soil quality.

5.2.3.3. Available water capacity (AWC)

Available water capacity is the capacity of a soil to hold water available to plants; it is usually expressed in inches of water per inch of soil depth. AWC is commonly measured with a pressure plate apparatus as the amount of water held by the soil at tensions between field capacity and wilting point (-33 and -1500 kPa); and is mainly determined by the pore size distribution of the soil.

Large quantities of water are needed to supply the evapotranspiration requirements of growing plants. Except in the areas of abundant and timely rainfall, most of it must come from the soil. Thus, the amount of water a soil can hold available for plant use is an important property (USDA, SCS 1983). Available water capacity is one of the soil properties most affected by erosion and management practices (Pierce et al. 1991, USDA,SCS 1981, Frye et al. 1982, Larson et al. 1985). One reason for this is because the silt fraction is the major factor that governs pore size distribution in a soil, which in turn affects AWC (USDA, SCS 1983). Because the silt component is very susceptible to erosion, accelerated erosion leads to reduced AWC.

Classes of AWC are not standardized throughout the country because of the different effects of AWC on plant production in different moisture regimes. In areas of the country where moisture is seldom in short supply, AWC has a minimum effect on plant production so the classes are based on a relatively thin root zone. In dryer areas, however, production of plants is highly dependent on AWC and classes are based on deeper depth (USDA, SCS 1983) (Table 5.2-3). The AWC classes listed in Table 5.2-4 will be used initially to interpret AWC values and rate soils based on AWC. A decrease in AWC based on these classes would be considered a warning of decline in soil quality.

Table 5.2-4. Ratings of available water capacity (AWC) by moisture regime [1/]

| AWC class | Aquic, Perudic (wet) in/40 in soil | Udic, Ustic (moderately wet) in/60 in soil | Aridic, Xeric(dry) in/60 in soil |
|---|---|---|---|
| very low | <2 | <3 | <2.5 |
| low | 2-3 | 3-6 | 2.5-5 |
| moderate | 3-4 | 6-9 | 5-7.5 |
| high | >4 | 9-12 | 7.5-10 |
| very high | - | >12 | >10 |

[1/] From: USDA, Soil Conservation Service 1983
Aquic soils are water-saturated long enough for reducing conditions to exist; in perudic regimes, precipitation exceeds evapotranspiration for every month of the year; in Udic regimes, soils are not dry as long as 90 cumulative days per year; in Ustic regimes soils are dry for more than 90 consecutive days per year; soils in Aridic regimes are never dry for more than 90 consecutive days and are dry for more than one-half the time when not frozen; in xeric moisture regimes soils are dry >45 consecutive days in the summer and wet >45 consecutive days in the winter (Buol et al. 1980).

In the Pilot, AWC will be measured in the top or surface 20 cm of soil. The range in AWC values for the lower horizons of the soil type will be obtained from the State Soil Survey Database. Later, if direct measurements of AWC in lower horizons seem important to obtain, we can explore the possibility of taking deeper soil cores.

5.2.3.4. 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 presence of inhibitory compounds (e.g., Al, salts), or a nutrient deficiency (e.g., P fixation), (Pierce et al. 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. The pH is higher in soils of arid regions than in humid regions, higher in younger soils than older soils, lower on flat topography than on steep slopes. Agriculture accelerates the process of soil acidification on many soils when soil liming is not practiced. For this reason, agricultural soils are often amended with liming compounds such as calcium carbonate.

Classes of soil pH used by the SCS are listed in Table 5.2-5. These ratings could be used to give a more qualitative interpretation of pH values. An increase in land in highly acid or highly alkaline classes would be interpreted as a warning of decline in soil quality. The use of liming amendments will be monitored as an indicator of the need to neutralize acidification. As the Program is implemented in western states, alkalinization processes would become more important.

Table 5.2-5. Ratings of soil pH [1/]

| Class | pH value |
|---|---|
| ultra acid | <3.5 |
| extremely acid | 3.5-4.4 |
| very strongly acid | 4.5-5.0 |
| strongly acid | 5.1-5.5 |
| moderately acid | 5.6-6.0 |
| slightly acid | 6.1-6.5 |
| neutral | 6.6-7.3 |
| mildly alkaline | 7.4-7.8 |
| moderately alkaline | 7.9-8.4 |
| strongly alkaline | 8.5-9.0 |
| very strongly alkaline | >9.0 |

[1/] From: USDA, Soil Conservation Service 1983

### 5.2.3.5. Base saturation

Base saturation is a measure of the proportion of base cations on the cation exchange sites of a soil. It is the most common measure of soil fertility with regard to available nutrients for plants and microorganisms, and would be an important parameter in a soil fertility index.

The data would be used to provide a broad-scale, long-term picture of base saturation in the top 20 cm of agricultural soils. An increase in the proportion of land area with a decrease in base saturation would be interpreted as an indicator of decline in soil quality (Ewel et al. 1991). The use of liming amendments would be monitored as an indicator of the need to increase base saturation.

### 5.2.3.6. Exchangeable acidity

Exchangeable acidity is a measure of the proportion of hydrogen and aluminum on the cation exchange sites of a soil. Exchangeable acidity is an indicator of possible chemical constraints to the growth of roots and other biological communities, including the presence of inhibitory compounds (e.g., aluminum, manganese) or a nutrient deficiency (e.g., P fixation) (Pierce et al. 1991). Interpreted together with pH, exchangeable acidity is a good measure of soil acidity. An increase in acid saturation or a soil acidity index would be considered an indicator of decline in soil quality (Ewel et al. 1991). The use of liming amendments would be monitored as an indicator of the need to neutralize acidification.

### 5.2.3.7. Exchangeable sodium percentage (arid soils).

The presence of large quantities of sodium in fine-textured soils is undesirable because of its degradative effect on soil structure (Tisdale and Nelson 1975). Irrigation is known to increase sodium content of soils because evaporation of saline water deposits salts in fields. A measure of sodium in soils is likely to become most important as the Program is implemented in western states with arid soils.

Plant growth in alkaline soil, especially for irrigated agriculture, depends critically on the exchangeable sodium percentage (ESP) of the soil. ESP is the proportion of sodium of the total exchangeable cations in the soil. Soil with greater than about 15% ESP deflocculates readily and is difficult to make or keep permeable. Soil with ESP in the range of 7.5-15% needs careful management, especially under irrigation. Where the ESP is less than 7.5% the soil is not appreciably affected by sodium. Therefore, the critical ratings in ESP are 7.5 and 15% (Webster and Oliver 1990, Russell 1973) (Table 5.2-6). An increase in the proportion of soils in the >7.5% class would be interpreted as an indicator of decline in soil quality. Other salinity measures, such as the sodium absorption ratio (SAR) will be evaluated in future pilots.

Table 5.2-6. General ratings for exchangeable sodium percentage [1/]

| Rating | Exchangeable sodium percentage |
|---|---|
| Not affected | <7.5 |
| Affected | 7.5-15 |
| Seriously affected | >15 |

[1/] From: Russell 1973, Webster and Oliver 1990

5.2.3.8. 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).

The electrical conductivity of a saturated extract is the standard measure of salinity. The standard international unit of measure of electrical conductivity is decisiemins per meter (dS/m) corrected to a temperature of 2.5 C. A value > 4 dS/m is considered a saline soil (Table 5.2-7). Therefore, an increase in the proportion of soils in a region with > 4 dS/m would be interpreted as a warning of decline in soil quality.

Table 5.2-7. Salinity ratings based on electrical conductivity [1/]

| Classes | Electrical conductivity (dS/m) |
|---|---|
| not saline | <2 |
| very slightly saline | 2-4 |
| slightly saline | 4-8 |
| moderately saline | 8-16 |
| highly saline | >16 |

[1/] From: USDA Soil Conservation Service 1983
1 dS/m = 1 mmhos/cm

5.2.3.9. Extractable aluminum (humid soils)

Extractable aluminum is a measure of trivalent aluminum ions ($Al^{3+}$) on the exchange sites of a soil. Aluminum is the main source of exchangeable acidity in soils and is responsible for the detrimental biological effects of soil acidification (Veitch 1902). The $Al^{3+}$ ion is the main species present at soil pH values of <5.0 and is the species most toxic to plants and soil microorganisms. Microbial processes known to be affected by exchangeable Al include symbiotic and nonsymbiotic nitrogen fixation (Cooper et al. 1985, Rosswall et al. 1985, Alexander 1985, Katznelson 1940), decomposition (Mutatkar and Pritchett 1966), and growth of soil fungi (Ko and Hora 1972). The concentrations of aluminum known to be toxic

or nontoxic to plants and soil microorganisms are available in the literature and could be compiled into a rating scale for interpretation of Al values.

5.2.3.10. Trace metals

Municipal sludge and industrial or urban waste water are commonly applied to agricultural soils as an organic amendment and a waste control strategy (Korentajer 1991). Atmospheric deposition also contributes to the presence of contaminants in soil. Nearly all the earth's surfaces have received atmospheric deposits of lead released from burning fossil fuels (Brams 1977, Page and Ganje 1970). Soils in some areas have received lead, cadmium and/or copper pesticide sprays containing these metals.

Although an active microflora will degrade most potentially harmful contaminants, the safety and desirability of waste application has been controversial because of the potential of gradual contamination of soils with toxic and persistent contaminants, such as trace metals, and the potential ecological effects. Municipal sludge (sewage sludge) applied to soils nearly always contain lead, cadmium, chromium, copper, nickel and zinc (Baker et al. 1979, Baker and Chesnin 1975).

Soil contamination with trace metals poses a direct risk of toxicity to plants, soil organisms and microbial functioning (Brookes and McGrath 1985). Vesicular-arbuscular mycorrhizal fungi, important plant symbionts in agroecosystems, are usually sensitive to high levels of trace metals (Tyler et al. 1989). Some contaminants are taken up by plant material and pose a risk of accumulation in grazing livestock and in humans.

In the 1992 pilot, mercury (Hg) levels in agricultural soils will be measured as an initial indicator of trace metal concentrations. Mercury contamination of the environment is a serious problem. Terrestrial ecosystems receive continuous fallout of Hg estimated at 100,000 tons annually (Lindsay 1979), from fossil fuels, Hg-consuming industry and natural evaporative losses from soils and rocks.

The natural mercury content of soils is depends on the nature of the parent material, pH, drainage and organic matter content (Stewart and Bettany 1982). Mercury occurs as a mineral at shallow depths. It has a high vapor pressure, is very volatile, and has the ability to form many organic and inorganic compounds and complexes (Lindsay 1979). Background levels are generally less than 100 µg/g soil (Stewart and Bettany 1982). In soils that have developed on shale or sedimentary deposits, the Hg content can range from 1 to 50 µg/g soil (Warren et al 1966) to 250 µg/g (Jonasson and Boyle 1971). Atmospheric fallout, application of municipal sludge, and seed fungicide treatments can result in elevated levels of Hg in the surface horizon of agricultural soils several orders of magnitude greater than background levels.

Mercury levels in the surface 20 cm of soil will be measured. The number of fields which have received applications of municipal sludge will also be determined. It is likely that there is enough available data in the scientific literature to determine potentially toxic levels of Hg for plants, animals, and soil organisms that could be compiled and used for the interpretation of Hg data. Additional trace metals may be included in further pilots.

5.2.3.11. Bulk density

Bulk density is an indicator of how well plant roots are able to extend into the soil (USDA, SCS 1983). Bulk density is expressed as soil weight per volume dry soil and generally ranges from about 1.0 to about 2.0 g/cm$^3$ in agricultural soils; Because bulk density is defined as the volume of both solids and pores, soils that are loose and porous will have low weights per volume (bulk density) and those that are compact will have higher bulk densities (Brady 1974). Soils that contain organic matter and have good aggregation have low bulk densities.

Bulk density is used as a 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). Bulk density as an indicator would be used to provide a broad-scale, long-term picture of bulk density in the top 20 cm of agricultural soils, and perhaps in lower soil horizons as the Program develops. An increase in the proportion of soils reaching critical bulk density values within their texture class would be interpreted as an indication of decline in soil quality. Bulk density would be an important component in a soil structure index.

Bulk density measurements are most accurate when taken in intact cores. However, because the procedure to obtain intact cores in the context of a large survey has not been developed, this indicator will not be measured directly in the 1992 Pilot. Bulk density data from the SSSD will be used in the 1992 Pilot for initial exploration of this indicator.

5.2.3.12. 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).

Both macro- and micropore spaces occur in soils. Although there is no sharp line of demarcation, macropores characteristically are those which allow the ready movement of air and percolating water. Air movement is generally impeded in micropores and water movement is restricted to capillary movement. Thus, in a sandy soil, in spite of the low total porosity, the movement of air and water is rapid because of the dominance of the macrospaces. In fine-textured soils, dominated by micropores, the total pore space is large but the micropores are usually filled with water. Aeration can frequently be inadequate, especially in the subsoil (the

soil below the plow layer), for satisfactory root development and desirable microbial activity. Therefore, the size of the individual pore spaces rather than their combined volume is the important consideration (Brady 1974). Soil porosity is the main response variable used in a conceptual model of changes in soil structure under different cropping systems (Gibbs and Reid 1988).

Two approaches will be taken to measure and interpret soil porosity. The first is similar to the work of Thomasson (1978), who used the relative proportion of macropores (>60µm) and mesopores (0.2µm to 60µm) to define four classes of soil structure. Pores greater than about 60 µm (termed air capacity) could be measured with a pressure plate at -5 kPa. Mesopores (termed available water) can be measured as the volume of water held between about -33 and 1500 kPa (same measurement as available water capacity). The best soil class has a macroporosity >= 15% and a mesoporosity of 20-35%. The worst class has a macroporosity >5% and a mesoporosity of <35% (Kay 1989). A second approach will measure the percent of soil volume occupied by pores of approximately 30 and 60µm (measured at -10 and -5 kPa with a pressure plate, respectively), which are important for water drainage and the survival, growth and movement of soil microflora and fauna (Duniway 1979). An increase in the proportion of soils in the lower classes of Thomasson's rating scale, and/or at the lower levels of porosity critical to microbial functioning, would be interpreted as an indication of decline in soil quality.

Porosity can be measured with a pycnometer on intact soil cores or with a pressure plate apparatus on nonintact cores. Because the procedure to obtain intact cores in the context of a large survey has not been developed, pressure plate measurements will be used initially.

5.2.3.13. Hydraulic conductivity (permeability)

Permeability or hydraulic conductivity is the quality of the soil that enables water or air to move through it and is determined by pore geometry. Hydraulic conductivity is especially important in drainage, water erosion and leaching potential of a soil. It is a main variable used

in the algorithm developed by Goss and Wauchope (1990) to calculate soil leaching potential of pesticides.

Hydraulic conductivity is a measure of the rate at which soil transmits water while saturated. Classes of hydraulic conductivity used by the SCS are listed in Table 5.2-8. These ratings could be used to give more of an qualitative interpretation to hydraulic conductivity values. An increase in the proportion of soils in the lower classes of the SCS rating scale would be an indication of decline in soil quality.

Hydraulic conductivity measurements are most accurate when taken on intact cores. The procedure to obtain intact cores in the context of a large survey has not been developed. Therefore, this indicator will not be directly measured in the 1992 Pilot. Hydraulic conductivity data from the SSSD will be used for initial exploration of this indicator.

Table 5.2-8. Ratings of hydraulic conductivity recognized by the SCS.[1/]

| **Hydraulic class** | **µm/s** |
|---|---|
| very low | <0.01 |
| low | 0.01-0.1 |
| mod low | 0.1-1 |
| moderate | 1-10 |
| high | 10-100 |
| very high | >100 |

[1/] USDA, SCS 1983

5.2.3.14. Erosion (water)

The Universal Soil Loss Equation (USLE) will be used as an estimate of erosion due to water. The USLE is a model of soil erosion developed in the 1950's from many years of field experimentation throughout the U.S. (Wischmeier and Smith 1978). The equation is designed to predict long-term losses of soil through sheet and rill erosion from specific land areas under specified cropping and management and is widely used by the SCS and conservation planners to determine appropriate soil management strategies. Although termed the *soil loss* equation, the USLE is actually an estimate of soil *movement* or *displacement* within a field, rather than an estimate of actual soil loss from the field.

The equation,

$$A=R*K*LS*C*P$$

groups six major factors whose site-specific values can be expressed numerically. The equation parameters are defined by Wischmeier and Smith (1978):

**A** Soil loss (displacement or movement within the field)

**R** The rainfall and runoff factor, is the number of rainfall erosion index units plus a factor for runoff from snowmelt or applied water where such runoff is significant.

**K** The soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6 ft length of uniform 9-percent slope continuously in clean-tilled fallow. The soil properties that influence soil erodibility are infiltration rate, permeability, total water capacity, and those properties that resist dispersion, splashing, abrasion and transportation forces of rainfall and runoff. The Soil Conservation Service has estimated K for most agricultural soils.

**LS** The slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6 ft. length under identical conditions; the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical condition.

C The cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P The support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

Data for the six USLE factors are obtained from field measurements (LS factor), from grower interviews (C and P factors), and from the State Soil Survey Database (K and R factors) (Table 5.2-9).

Table 5.2-9. Sources of data for the six Universal Soil Loss Equation (USLE) factors.

| USLE parameter | Data source |
|---|---|
| R | Published maps (U.S. or state, e.g. Wischmeier and Smith, 1978 or USDA/SCS 1990), State Soil Survey Database or STATSGO |
| K | State Soil Survey Database, State SCS USLE Technical Guides (e.g. USDA/SCS 1990) or STATSGO |
| L | Field - *procedure needs development* |
| S | Clinometer measurement - *needs development* |
| C | Calculated by EMAP staff from technical guides (e.g. Wischmeier and Smith, 1978 or USDA/SCS 1990) and site-specific data on crop type and tillage practices (data questionnaire) - *estimate may be rough - procedure needs development* |
| P | Calculated by EMAP staff from technical guides (e.g. Wischmeier and Smith, 1978 or USDA/SCS 1990) and site-specific data on crop type, slope, and tillage practices (data questionnaire) - *estimate may be rough - procedure needs development* |

The soil erosion tolerance factor (T) is also available from the SSSD and is used in the interpretation of the USLE values (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 tons per hectare per year for shallow or otherwise fragile soils to eleven tons per hectare per year for deep soils that are least sensitive to damage by erosion (see Table 5.2-17).

The goal of soil erosion estimates as an indicator is to provide a regional, long-term picture of soil erosion due to water. Spatial and temporal patterns in soil erosion could be evaluated with respect to other Agroecosystem indicators (land use, crop productivity, agrichemical use and soil chemical, physical and biological measurements). For the initial exploration of this indicator, the data from the SCS National Resource Inventory (NRI) on soil erosion will be used (USDA 1989). The SCS has national soil erosion data from 1982 and 1987 that allow analysis at a substate (multi-county) level. The NRI for 1992 is in progress. If it is determined that NRI data are not adequate for the desired assessments, procedures for measuring USLE factors from points within sampling fields would be developed. First, the procedure for extrapolation of the point-based S and L measurements to a field basis will be addressed, and protocols for NASS enumerators or other field staff developed. Then methods and algorithms for automating the computation of the C and P factors from data in the NASS survey questionnaire would be derived.

### *5.2.4. Logistics*

Each NASS enumerator will sample approximately 10-15 segments and receive a kit containing the items listed in Table 5.2-10 at the NASS training session. Within the enumerator kit will be a soil sampler/probe set. In the probe set, three tips will be available for the core tube for sampling soil under a range of conditions. The regular (2 notches), mini (1 notch), and super (4 notches) duty tips are for sampling moist, dry, and stony soils, respectively. Extra parts will be available at 1509 Varsity Drive, Raleigh, NC 27606 (Agroecosystem Program headquarters) and can be shipped by overnight express delivery upon demand. Several phone numbers, where

**Table 5.2-10.** Contents of the enumerator kit

| Item | Purpose |
|---|---|
| Manual describing sampling methods | |
| Indication of whether that field will be sampled in duplicate or not | internal check of laboratory variability |
| 3-foot hinged ruler | measure 45° angles for transect |
| stakes (20 red, 10 yellow) | marking transect and location of soil cores along the transect |
| 36-inch Oakfield probe set [contains 12" handle, 2 12" extension rods, 12" tube which extracts a sample 8" long x 13/16" diameter, 3/4 " tips for moist, dry, and stony soil, a footstep for dry or compacted soils, and a fiberboard case] | collect 20 20-cm deep cores |
| Extra 12" core tube | in case the core in the kit becomes twisted |
| 14-qt. plastic bucket with handle | collect and homogenize soil cores |
| 2 500-ml plastic beakers | measure volume of soil for nematode and chemical/physical analysis; 2 are included in the kit to allow 1 extra |
| 4 x 2 x 12" plastic bags | store 500 ml soil sample for nematode enumeration at the moisture content of the field |
| 3 qt. plastic bags | mail samples back to preparation lab. |
| Pre-labeled paper-wire tags -write sample number on the label twice, one above the other | labeling nematode samples appropriately for enumeration laboratory |
| 2 polystyrene ice chests | lightweight, insulated container for storage of samples in an environment to prevent lethal temperatures |
| Pre-printed mailing labels | tracking samples from field to analysis laboratories |
| Postage-paid container for mailing | transporting samples for chemical/physical analysis directly to analysis laboratory |
| Postage-paid, insulated container for mailing | transporting samples for enumeration of nematodes |
| Roll of strapping tape with cutting edge | packaging samples for mail |
| Postcards | tracking of samples that are mailed |

someone could be reached at all times, will be included in the enumerator's manual for use in the event of equipment loss or breakage.

**Sample collection.** For each field, the enumerator will be given the following information printed on their survey form: the sample number(s), whether or not a second composite sample must be collected in that field, and the number of paces along and into the field to determine the midpoint of the sampling transect. Two labels will be provided for composite samples that will be divided into duplicate samples at the preparation laboratory. All labels will be printed in cooperation with the North Carolina Agricultural Statistics Division in Raleigh (an office of NASS). The sampling design was constructed to include measures of within-field variability (a second composite sample collected for every sixth field sampled) and within-sample or laboratory variability (duplicates are taken from the second composite sample from every twelfth field) (see Appendix 7). The enumerator will collect soil cores according to the sampling design described in Section 3.3.2. Example instructions for the NASS enumerators are listed in Appendix 6.

Twenty cores (2-cm diameter) of soil are necessary to provide enough soil (1256 $cm^3$) for the required analyses. Total soil volume of each composite sample must exceed 500 plus 550 $cm^3$, the respective volumes required for chemical/physical analysis and nematode enumeration (Section 5.6.4). The volume designated for nematode enumeration contains 50 $cm^3$ for calculation of the volume:weight ratio described in Section 6.1.4. When a field is selected for a duplicate sample (Appendix 7), 40 cores per transect will be required to collect enough soil for all laboratory determinations.

Within each field, one core will be taken at each of 20 locations, except for duplicate samples where two cores will be taken at each of 20 locations, equally spaced along a 100 yard diagonal transect (Section 3). For each core, the soil tube will be pushed *straight* down into the soil, without twisting, to the depth that fills the entire 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, another core will be taken in the same location within 15 cm. When all 20 cores have been deposited into the bucket the enumerators will be instructed to mix the soil thoroughly by hand, breaking up

soil clumps *gently*. Any rocks larger than 2 cm in diameter will be discarded, but all surface organic matter should be kept as part of the soil sample. When appropriate, soil for nematode enumeration (Section 6.1) will first be removed. Pre-labeled mailing containers will then be filled with soil for the chemical and physical analyses, and stored in an insulated container (ice chest). Samples will be mailed the same day they are collected or first thing the next day through Federal Express (1-800-238-5355 for pick-up). Sample(s) will be mailed to the preparation laboratory (Attn: Charles Harper, Box 7616, North Carolina State University, Raleigh, NC 27695) in the pre-addressed, postage-paid container. Postage will be paid using a Federal Government account through the Air Resources Research Consortium at North Carolina State University.

**Laboratory analyses--physical and chemical.** ARG personnel will air-dry, homogenize, and grind the samples in the preparation laboratory according to specifications listed in Appendix 4. Then all samples will be mailed to the analysis laboratory in batches of approximately 40 samples. Within each box will be a list of the enclosed samples.

The analysis laboratory will analyze the soil samples for the specified chemical and physical parameters using the prescribed procedures (Table 5.2-11). Detailed laboratory procedures are described in Appendix 4. Reporting units and precision are listed in Table 5.2-12.

**Future activities.** The relationship between slope and fertility must be quantified and evaluated. The evaluation could result in future division of fields by slope region, with separate composite samples taken from each slope region. A decision to divide fields into subregions has the disadvantage that soil samples may be collected on a unit smaller than a whole field (a 5-acre area), which is the unit size for most other indicators.

Indicators of soil compactness are important because distribution and size of pore spaces is important for root growth, distribution of soil microbes, and earthworm populations; the activity of microbes and earthworms improve soil fertility and porosity, respectively. Potential indicators include bulk density, pore size distribution, or surrogate measures of compaction such as

**Table 5.2-11.** Soil analytical laboratory parameters to be measured in the 1992 Pilot.

| Parameter | Description of Parameter |
|---|---|
| %WATER | Air-dry soil moisture determined gravimetrically and expressed as a percentage on an oven-dry weight basis; mineral soils are dried at 105 C, organic soils at 60 C |
| SAND | Sand is the portion of the sample with particle diameter between 0.05 mm and 2.0 mm; it is measured using a hydrometer method |
| SILT | Silt is the portion of the sample with particle diameter between 0.002 mm and 0.05 mm; it is measured as [100 minus (SAND + CLAY)] |
| CLAY | Clay is the portion of the sample with particle diameter less than 0.002 mm; it is measured using a hydrometer method |
| EC | Electrical conductivity determined in a deionized water extract using a 1:1 mineral soil to solution ratio or 1:4 organic soil to solution ratio; it is measured with an electrical conductivity meter |
| PH_H20 | pH determined in a deionized water extract using a 1:1 mineral soil to solution ratio or 1:4 organic soil to solution ratio; it is measured with a pH meter and combination electrode. |
| XCA | Exchangeable calcium determined in a buffered (pH 7.0) Mehlich III extract using direct current plasma. |
| XMG | Exchangeable magnesium determined in buffered (pH 7.0) Mehlich III extract using direct current plasma. |
| XK | Exchangeable potassium determined in buffered (pH 7.0) Mehlich III extract using direct current plasma. |
| XNA | Exchangeable sodium determined in buffered (pH 7.0) Mehlich III extract using direct current plasma. |
| XAL | Exchangeable aluminum determined in buffered (pH 7.0) Mehlich III extract using direct current plasma. |
| CEC | Cation exchange capacity will be calculated as the concentration (meq/100g) of the exchangeable cations plus acidity. |
| ACIDITY | Total exchangeable acidity is a measure of the exchangeable acidic cations on the soil cation exchange complex. It will be determined in an unbuffered (pH 8.2) barium chloride triethanolamine solution using a 1:30 soil to solution ratio and a back titration procedure |
| BASE | Percent base saturation; may be calculated as the sum of exchangeable Ca, Mg, K and Na divided by CEC |
| MIN_N | Mineralizable nitrogen is a good predictor of soil nitrogen availability due to biological activity; an incubation technique for determination of anaerobic nitrogen as ammonium nitrogen is preferred. |
| P | Extractable phosphorous determined by a Bray II extractant using direct current plasma. |

**Table 5.2-11.** (cont'd)

| Parameter | Description of Parameter |
|---|---|
| ORG_C | Easily oxidizable humus determined as loss by combustion at 350 C. |
| Hg | Total mercury analyzed as a cold vapor using atomic absorption spectrometry. |
| kPa | Soil moisture determined on nonintact cores at -33 and -1500 kPa (-0.3 and -15 bars) and -10 kPa and -5 kPa (-100 and -50 mbars) soil matric potential using a pressure plate apparatus. The first measurements are those of permanent wilting capacity and field capacity for calculation of water available for plant extraction. The latter two tensions are those required to drain soil water from pores of size important for microbial survival and movement (i.e., approximately 30 and 60 µm diameter), respectively. |

**Table 5.2-12.** Reporting units, precision and expected concentration ranges (December 1990)

| Parameter | Reporting units[1/] | Reporting precision[2/] | Expected range (median)[3/] |
|---|---|---|---|
| %WATER | wt% | 1.0 | |
| SAND | wt% | 1.0 | 15.7-88.1 (70.2) |
| SILT | wt% | 1.0 | 3.4-56.9 (23.9) |
| CLAY | wt% | 1.0 | 1.0-20.0 (5.1) |
| EC | dS/m | 1.00 | 0.14-0.38 (0.23) |
| PH_H20 | pH units | 1.00 | 4.6-6.6 (5.7) |
| XCA | meq/100g | 1.00 | 1.07-9.72 (3.14) |
| XMG | meq/100g | 1.00 | 0.28-3.02 (1.04) |
| XK | meq/100g | 1.00 | 0.13-0.67 (0.35) |
| XNA | meq/100g | 1.000 | 0.03-0.10 (0.04) |
| XAL | meq/100g | 1.0 | 0.01-0.98 (0.52) |
| CEC | meq/100g | 1.00 | 2.5-21.9 (6.2) |
| ACIDITY | meq/100g | 1.00 | 1.5-45 (24) (%) |
| BASE | % | 1.00 | 47.0-94.0 (76.0) |
| MIN_N | mg N/100g | 1.0 | |
| P | mg P/kg | 1.0 | 13-195 (76.5) |
| ORG_C | wt% | 1.0 | 0.7-19.4 (2.1)[4/] |
| Hg | mg Hg/kg | 1.0 | |
| kPa | vol% | 1.0 | |

[1/] All values expressed on an oven-dry soil weight basis.
[2/] Number of decimal places that each unit should be determined for
[3/] Expected concentration ranges in reporting units for soil samples, based on the 1st, 95th, and (50th) percentiles of data collected from previous surveys.
[4/] Estimated from organic matter determinations.

hydraulic conductivity or water infiltration rate. These measurements require either intact cores or complicated protocols. They were not included in the 1992 Pilot Project because the logistical concerns had not been resolved, but they will be studied for inclusion in a 1993 pilot.

### *5.2.5. Quality Assurance / Quality Control*

**Samples.** Each sample will be enclosed in a pre-labeled container, with a unique sample number from 1 to 447 (Appendix 7). The code number will not reveal the actual location of the field where the sample was collected. The containers will not contain contaminants that would bias or interfere with detection of chemical parameters and will be provided by or purchased from the analysis laboratory. The date the sample was collected, mailed, and received by the preparation laboratory will be recorded on the mailing container using permanent ink. A pre-addressed postcard will be mailed by the NASS enumerator to the ARG information manager (1509 Varsity Drive, Raleigh, NC 27606) for each sample at the same time the sample is mailed to analysis and preparatory laboratories to facilitate tracking of samples.

The analysis laboratory will be provided with a list of soil samples in each container shipped. As each sample is received, the date of receipt will be recorded by laboratory personnel in a log that later will be returned to ARG personnel.

**Laboratory analyses.** Five private laboratories and one federal laboratory (Table 5.2-13) were compared for analysis methods and costs for a specified list of desired soil analyses, analysis procedures (Table 5.2-11) and QA/QC requirements (Table 5.2-12). An official bidding process will be conducted through USDA-ARS based on the desired procedures and cost. These results will provide justification for selection of a laboratory for analysis of chemical and physical parameters of the soil samples.

A legal contract or interagency agreement will be written with the contract laboratory to address the following topics: analysis precision and method of determining precision, cost, and time of completion of analyses. Laboratory accuracy will be determined by including one known

**Table 5.2-13.** Private and federal laboratories contacted for chemical and physical analysis of soils.

HUFFMAN LABORATORIES, INC.
4630 Indiana
Golden, CO 80403
Contact: Suzanne J. Zeller, Technical Services Coordinator
303/278-4455

WEYERHAEUSER ANALYTICAL AND TESTING SERVICES
32901-32 Drive, S.
Federal Way, WA 98003
Contact: Ron Isaacson
206/924-6149

MICRO-MACRO INTERNATIONAL (MMI)
183 Paradise Blvd., Suite 108
Athens, GA 30607
Contact: J. Benton Jones, Jr.
404/548-4557

AGRICO RESEARCH LABORATORY
P.O. Drawer 639, 1087 Jamison Road N. W.
Washington Court House, OH 43160
Contact: Scot Anderson
800/321-1562

BROOKSIDE FARMS LABORATORY
308 South Main St.
New Knoxville, OH 45871
Contact: Mark Flock
419/753-2448

SCS NATIONAL SOIL SURVEY LABORATORY
Federal Building, Rm 152
100 Centennial Mall North
Lincoln, NE 68508-3866

sample for every 40 samples submitted to the analysis laboratory (see Appendix 7). Laboratory discrepancy can be statistically removed from estimates of within-field variability to permit greater accuracy of variance estimates.

The data from chemical/physical analyses will be sent as an ASCII file on diskette to the ARG information manager. The ARG information manager will perform validation tests on the data to determine whether the values for each parameter fit within the expected range (Table 5.2-12) and precision objectives established for within-laboratory analysis and within-field variability (Table 5.2-14). The outlier samples will be resubmitted to the laboratory for a second analysis.

**Table 5.2-14.** Data quality objectives for measurement of soil samples within the analytical laboratory and within fields (October 1991, Wake and Johnson Counties, NC)

| | | Precision objectives [1] | | | |
|---|---|---|---|---|---|
| | Reporting | Laboratory | | Field | |
| Parameter | units | SD | %CV | SD | %CV |
| SAND | wt% | 12.83 | 19.0 | 15.04 | 23.0 |
| SILT | wt% | 6.60 | 38.6 | 7.40 | 41.7 |
| CLAY | wt% | 9.90 | 63.9 | 11.72 | 69.3 |
| EC | dS/m | 0.083 | 32.1 | 0.106 | 38.5 |
| PH_H20 | pH units | 0.363 | 6.4 | 0.585 | 10.3 |
| XCA | meq/100g | 1.246 | 40.7 | 1.647 | 50.8 |
| XMG | meq/100g | 0.395 | 40.2 | 0.501 | 49.2 |
| XK | meq/100g | 0.173 | 56.2 | 0.195 | 60.8 |
| XNA | meq/100g | 0.027 | 50.6 | 0.024 | 45.7 |
| XAL | meq/100g | 105.46 | 13.8 | 139.76 | 18.1 |
| CEC | meq/100g | 1.842 | 29.2 | 2.356 | 35.2 |
| ACIDITY | meq/100g | 9.50 | 37.3 | 13.97 | 53.7 |
| BASE | % | 9.50 | 12.8 | 13.97 | 18.9 |
| MIN_N | mg N/100g | | | | |
| P | mg P/kg | 46.82 | 47.4 | 63.7 | 64.8 |
| ORG_C[2] | wt% | 0.999 | 44.7 | 1.065 | 45.0 |
| Hg | mg Hg/kg | | | | |
| kPa | vol% | | | | |

[1] For the field samples, objective is 2X analytical samples.
[2] Estimated as % organic matter
% CV = $\frac{\text{standard deviation}}{\text{mean}} \times 100$

All samples must pass laboratory precision tests. Submitted samples will be archived at the analysis laboratory until laboratory personnel are notified that all analyses passed the precision tests. After all data have been collected, validated and transformed (as needed), the ARG information manager will work with NASS personnel to integrate the soils data into the larger Agroecosystem Pilot dataset at the North Carolina Agricultural Statistics Division (Raleigh).

### *5.2.6. Metadata requirements*

In addition to the analysis data, metadata will be recorded to permit future interpretation of the database. Metadata will include methods of analysis, reporting units, whether data are integers or characters, name of analysis laboratory, and comments recorded during sampling or processing procedures (Table 5.2-15).

### *5.2.7. Data Analysis*

A major objective of the pilot study is to determine the range of values and the within- and among-site variance for each indicator. Pilot data will be supplemented with that from literature searches and from the State Soil Survey Database (SSSD). The ranges are needed for data editing programs as part of the quality assurance procedures. Ranges and estimates of variance are also needed, in combination with data from the literature, to determine what magnitude of change in indicator values is likely to occur and if this magnitude could be measured at the regional scale.

The main statistical presentation of data in the Pilot and in the implemented program will be cumulative distributions of indicator values in a region and interpretation of the values as the proportion or amount of land in a region that has values of concern with regard to soil quality. For example, the proportion of land with electrical conductivity values > 4 mmhos may indicate the proportion of land affected by salinization (Figure 5.2-1). The initial focus will be on cropland only; this focus will be expanded in the future to include other soils in agroecosystems (e.g., idle land, land adjacent to cropped fields, and land in the Conservation Reserve and other set-aside programs).

**Table 5.2-15.** Metadata for chemical and physical analysis of soils.

| Variable | Type | Unit[1/] | Anal. Method | Lab | Comments |
|---|---|---|---|---|---|
| %WATER | Integer | wt% | gravimetric | AGRICO[2/] | |
| SAND | Integer | wt% | hydrometer | AGRICO | |
| SILT | Integer | wt% | hydrometer | AGRICO | |
| CLAY | Integer | wt% | hydrometer | AGRICO | |
| EC | Integer | dS/m | 1:1 soil:sol | AGRICO | |
| PH_H20 | Integer | pH units | 1:1 soil:sol | AGRICO | |
| XCA | Integer | meq/100g | Mehlich III | AGRICO | |
| XMG | Integer | meq/100g | Mehlich III | AGRICO | |
| XK | Integer | meq/100g | Mehlich III | AGRICO | |
| XNA | Integer | meq/100g | Mehlich III | AGRICO | |
| XAL | Integer | meq/100g | Mehlich III | AGRICO | |
| CEC | Integer | meq/100g | calculated | AGRICO | |
| ACIDITY | Integer | meq/100g | BaCl 1:30 | AGRICO | |
| BASE | Integer | % | Ca+Mg+K+Na/CEC | AGRICO | |
| MIN_N | Integer | mg N/100g | $KMn_7O_4$ | AGRICO | |
| P | Integer | ppm | Bray II | AGRICO | |
| ORG_C | Integer | wt% | Combustion | AGRICO | |
| HG | Integer | mg/kg | Color vapor | AGRICO | |
| kPa | Integer | vol% | pressure plt | AGRICO | |

[1/] All values expressed on an oven-dry soil weight basis.
[2/] Used as an example laboratory.

Pilot data will be used to begin an evaluation of how well the indicators and derived indices truly reflect good, poor, or changing conditions. Although identified ranges for indicators and benchmark references of soil quality are generally lacking, soil ratings based on specific soil uses, properties or functions are available (see sections on individual indicators and Table 5.2-18) These soil ratings can be explored for application to regional soil quality monitoring. Because

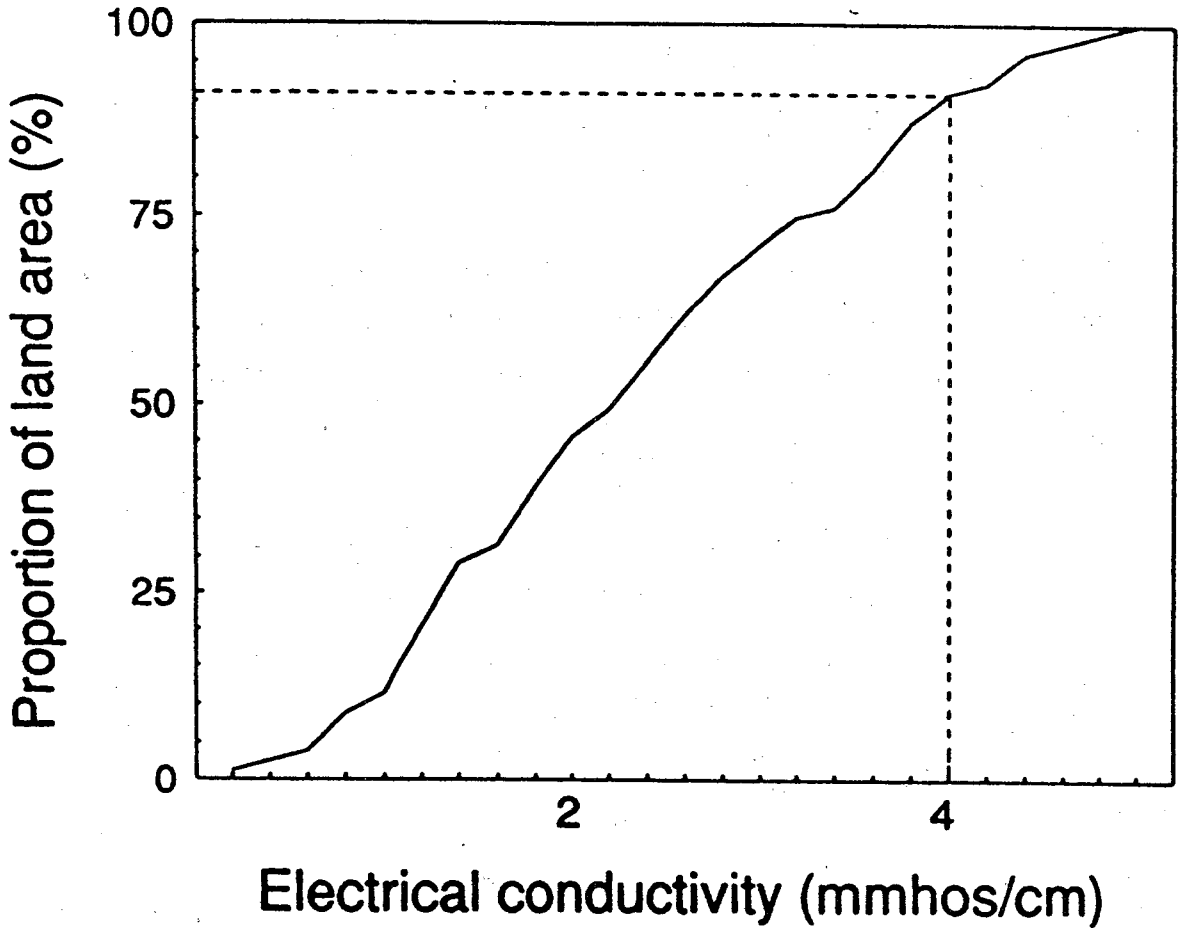



Figure 5.2-1. An example of a cumulative distribution function: electrical conductivity of soil.

indicator values will vary with climate, soil and management scenarios, general baseline reference points with which to group soils and sampling sites for indicator evaluation are needed. One approach may be to use the SCS Land Capability Classification (Table 5.2-16) as a reference standard (USDA 1961). One could assign each data point from the pilot into one of the 5 classes and to determine if the indicator values reflect better or poorer soils as defined by this soil rating scheme. In subsequent pilots, specific reference sites might be sampled, such as Class I (very good) and Class IV (very poor) soils or soils known to be poorly managed and degraded.

Determination of the *rate of change* of soil quality (change in the proportion of land area with specific ranges in indicator values) is an important long-term objective. Because the program is designed to give regional estimates of each indicator and standards of soil quality will vary with climate and soil, some grouping of the data will probably be necessary (see Section 5.2.7.1) (Webster and Oliver, 1990).

Using soil quality data to form a larger picture of agroecosystem condition is a long-term goal of the Program. Some aspects might be explored with Pilot data, perhaps supplemented by NRI and SSSD data, where needed. One type of assessment would be to explore spatial patterns of soil "stresses" and soil quality indicators. For example, patterns of land use or of soil erosion could be compared with those of soil structure indicators (i.e., AWC, porosity, clay content, organic C) on a regional scale. Trends in soil indicators might be compared with trends in overall implementation of soil conservation practices. However, it should be emphasized that ascribing a cause to observed indicator values or trends (e.g., soil erosion effect on soil structure) is ***not*** a goal of the regional monitoring and assessment component (called Tier 2 in EMAP). Rather, associations among Tier 2 data are meant to be an initial look at broad spatial or temporal relationships. If broad assocations are observed, more extensive sampling and/or research would be initiated to determine if a cause and effect relationship exists.

Table 5.2-16. SCS Land Capability Classes

| Class | Description |
|---|---|
| Class I | Soils have few limitation that restrict their use |
| Class II | Soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices |
| Class III | Soils have severe limitations that reduce the choice of plants or that require special conservation practices or both. |
| Class IV | Soil have very severe limitations that reduce the choice of plants or that require very careful management |
| Class V | Soils are not likely to erode but have other limitations, impractical to remove, that limit their use |
| Class VI | Soils have severe limitations that make them generally unsuitable for cultivation |
| Class VII | Soil have very severe limitations that make them unsuitable for cultivation |
| Class VIII | Soil and miscellaneous area have limitations that nearly preclude their use for commercial crop production |

*Capability subclasses* are soil groups within one class and reflect major limitations such as risk of erosion, water in or on the soil surface that interferes with plant growth or cultivation, shallow, stony or droughty soils or a very cold or very dry climate.

5.2.7.1 Soil spatial variability and statistical approaches

The spatial and temporal variability of many soil properties is large and may make real changes in soil quality difficult to detect. Because EMAP is designed to provide regional estimates of indicator values, some aggregation will likely be necessary to minimize the broad inherent differences among agricultural soils. Several methods used to group soils according to taxonomic classes or soil properties would be appropriate for EMAP data. These include:

- Derived geographic classifications such as the Land Resource Regions and Major Land Resource Areas (USDA, SCS 1981)
- Taxonomic order or suborders (Figure 5.2-2)
- General landscape position or slope (Stone et al. 1985, Larson et al. 1983)
- Soil depth (Larson et al. 1983, 1985)

These aggregation groups are described briefly below. The 1992 Pilot was not designed to address how many samples are needed for different aggregation approaches, but the range of data values across the three physiographic regions of North Carolina may allow some initial exploration of these approaches. Data not collected directly that would be required to group each sample into the suggested aggregations are available in the SSSD.

**Derived geographic classifications.** Two of the most important technical groups and their derived geographic classifications are: Land Resource Regions and Major Land Resource Areas (MLRA) (USDA, SCS 1981). A MRLA can be treated as an agroecological zone with a relatively homogeneous pattern of soils, climate, water resources and land use (McCracken et al. 1985). Examples of the use of MLRA's in soil quality assessment include Larson et al. (1983) who estimated soil erosion rates and changes in productivity in two MLRA's broken down by slope class, and Turner et al. (1986) who aggregated data by MLRA's in an assessment of soil characteristics that indicate sensitivity to acidic deposition. Land Resource Regions are larger aggregations of MLRA's.

**Taxonomic groups.** The soil classification system used by the National Cooperative Soil Survey (SCS county-based soil surveys) is based on properties related to soil development and allows the placement of soil series into broader groups for progressively more general interpretations: soil families, subgroups, great groups, suborders and orders (USDA 1975). The general soil map of the USA identifies 27 suborders of soils that have been delineated in 61 areas (Figure 5.2-2). The most appropriate grouping of soils for statistical analysis is likely to be at the level of soil orders, suborders, or great groups (Larson et al. 1985). Ten soil orders are recognized. The differences among orders reflect the dominant soil-forming processes and the

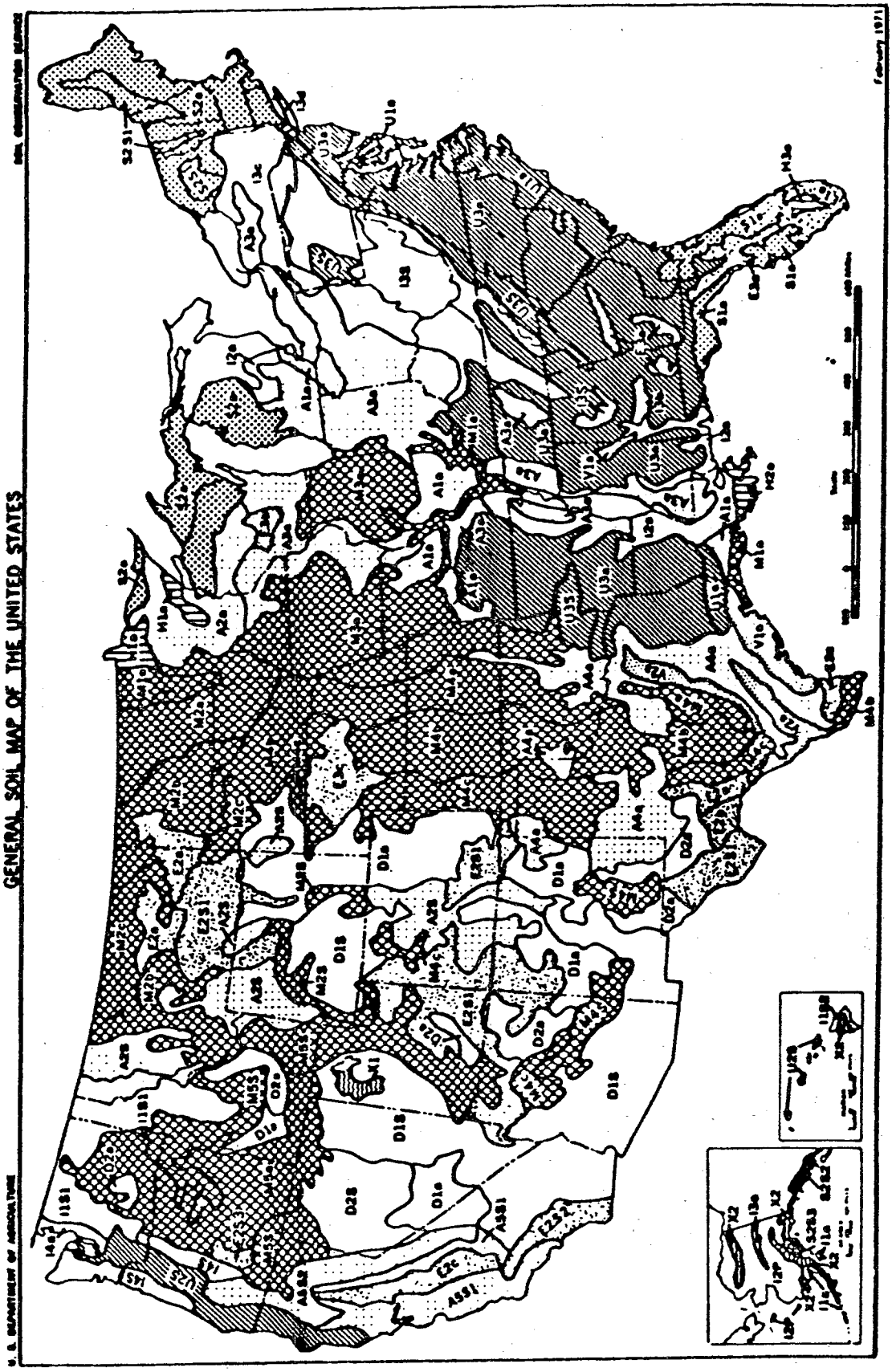



Figure 5.2-2. General soil map of the USA (USDA 1975). Map scale is approximately 1:20 million. See Figure 5.2-2 cont'd., second column, for explanation of the map unit symbols.

Figure 5.2-2 (cont'd). Soil orders and suborders in the U.S. (USDA,SCS 1981; Hall et al. 1985).

| Order and Suborder | Map symbol | Land Area (%) |
|---|---|---|
| Alfisols | | 13.4 |
| Aqualfs | A1 | 1.0 |
| Boralfs | A2 | 3.0 |
| Udalfs | A3 | 5.9 |
| Ustalfs | A4 | 2.6 |
| Xeralfs | A5 | 0.9 |
| Aridisols | | 11.5 |
| Argids | D1 | 8.6 |
| Orthids | D2 | 2.9 |
| Entisols | | 7.9 |
| Aquents | E1 | 0.2 |
| Orthents | E2 | 5.2 |
| Psamments | E2 | 2.2 |
| Histosols | H | 0.5 |
| Inceptisols | | 18.2 |
| Andepts | I1 | 1.9 |
| Aquepts | I2 | 11.4 |
| Ochrepts | I3 | 4.3 |
| Umbrepts | I4 | 0.7 |
| Mollisols | | 24.6 |
| Aquolls | M1 | 1.3 |
| Borolls | M2 | 4.9 |
| Udolls | M3 | 4.7 |
| Ustolls | M4 | 8.8 |
| Xerolls | M5 | 4.8 |
| Spodosols | | 5.1 |
| Aquods | S1 | 0.7 |
| Orthods | S2 | 4.4 |
| Ultisols | | 12.9 |
| Aquults | U1 | 1.1 |
| Jumults | U2 | 0.8 |
| Udults | U3 | 10.0 |
| Vertisols | | 1.0 |
| Uderts | V1 | 0.4 |
| Usterts | V2 | 0.6 |
| Areas with little soil | X | 4.5 |

degree of soil formation. Each order is divided into suborders primarily on the basis of properties that influence soil genesis and are important to plant growth or properties that reflect the most important variables within the orders. Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of horizon development; soil moisture and temperature regimes; and base status. The range of values for each indicator would be much smaller, and trends more likely detectable, if soils were aggregated at some taxonomic levels during data analysis.

**Topographic position.** Recent studies have shown that spatial variation in soil properties is controlled mainly by topographic position (Stone et al. 1985; Daniels et al. 1987, Ovalles and Collins 1986, Pierce et al. 1991). Lower slope soils are nearly always more fertile (and less susceptible to change or degradation) than ridgetop or upper slope soils. Compositing or bulking soil samples within and across sample fields with topographic variability will reflect primarily the properties and changes in the more fertile bottomland soils. Because topographic position and erosion are not mutually exclusive, and are confounded mainly by water relations, Stone et al. (1985) and others conclude that much published data dealing with the effects of erosion on plants and soil are confounded by the effect of topographic position.

Changes in soil quality due to erosion and management practices will likely be undetectable in some topographic positions such as bottomland soils, while changes in ridgetop soils may be of substantial importance. Therefore, stratified within-field sampling according to slope and/or interpretation of indicators within slope classes (Larson et al. 1983) will likely be necessary at some time in the development of the program. This will require exact protocols for the enumerator on when and how to divide fields for sampling and/or how to determine the slope at the sample point. Field sampling methods for the 1992 Pilot that minimize within-field spatial variability will be chosen (see Section 3 and 5.2.4) but will not include slope considerations at this time. Field sampling will be reevaluated after the 1992 pilot for subsequent pilots.

**Soil depth.** Degradation of irreplaceable soil attributes is much more serious on some soils than on others when compared at the same erosion rates (Larson et al. 1983, Hall et al. 1985).

For example, a deep alluvial soil is much less vulnerable to degradation by erosion, in the short term, than is a shallow, weathered soil, or soils with biologically unfavorable subsoils. For this reason, soil depth is used as the basis for determining SCS soil loss tolerance (T) values (Table 5.2-17). Soils could be post-stratified according to horizon depth when interpreting soil quality indicators; the depth of each soil mapping unit is available in the SSSD.

Table 5.2-17. Examples of using soil depth for assigning soil loss tolerance values to soils. [1/]

| Soil depth | Renewable soil [2/] | Nonrenewable soil [3/] |
|---|---|---|
| cm | t/ha | t/ha |
| <25 | 2.2 | 2.2 |
| 25-51 | 4.5 | 2.2 |
| 51-102 | 6.7 | 4.5 |
| 102-152 | 9.0 | 6.7 |
| >152 | 11.2 | 11.2 |

[1/] From: USDA-SCS 1983; Hall et al. 1985
[2/] Soils that have a favorable substratum and can be renewed by tillage, fertilizer, organic matter and other management practices
[3/] Soils that have an unfavorable substratum, such as rock, and that cannot be renewed economically

### *5.2.8. Research Goals and Applications*

Long-term assessment of soil quality has become a high priority for agroecologists (McCracken et al. 1985, Shirley 1991, Pierce et al. 1991, Haberern 1991). The World Resources Institute listed soil condition and extent of degradation as high priority environmental information needed for decisionmakers (WRI 1991). The earliest soil assessments for agroecosystems attempted to develop numerical ratings of soil productivity and were motivated by the need to compare different soils for purposes of land use planning and tax assessments. These ratings

were based primarily on crop yield (Huddleston 1984). Several newer soil *productivity models* are based on soil properties such as bulk density and texture, often with the goal of predicting the effect of accelerated soil erosion on long-term crop yields (Williams et al. 1984, Pierce et al. 1983, Kiniry et al. 1983, Huddleston 1982). The Soil Conservation Service is currently developing a new Soil Rating for Plant Growth, which is also based on soil properties (Ray Sinclair, SCS, Lincoln, NE, personal communication 1992). Because soil structure is central to the functioning of soils and is susceptible to long-term damage from intensive agriculture, attention is also being given to conceptual models that characterize soil structure and the rate of change due to agricultural land management (Kay 1989, Gibbs and Reid 1988, Thomasson 1978).

Table 5.2-18 lists several examples of published work on soil assessments that will be useful for identification of ranges for indicator values (e.g., USDA-SCS 1983) and in the development of indices of soil quality (e.g. Lal 1991, Singh et al. 1992, Pierce et al. 1983, Kiniry et al. 1983, Huddleston 1982, Thomasson 1978). The basis for establishing rating scales to interpret indicator values should ultimately include not only the capacity of the soil to sustain crop production, but should also allow for interpretation of how changes in soil indicators affect soil organisms, nutrient cycling, soil resiliency, vulnerability to erosion and thresholds of irreversible change. For example, soil porosity values, and changes over time, could be interpreted in the context of microbial ecology as well as adequate aeration for root growth.

Many of the assessments listed in Table 5.2-18 combine and query GIS databases on a regional or national scale (Burke et al. 1989, Turner et al. 1986, Nielsen and Lee 1987, Bliss and Reybold 1989). Examples of soil assessments conducted on a regional scale include soils or land area likely to be sensitive to intensive agricultural use (Federoff 1987, Yassoglou 1987), sensitive to acid deposition (Turner et al. 1986) or susceptible to organic matter loss (Burke et al. 1989). Goss (1991) develped a rating scheme of the soil leaching potential of agricultural chemicals that has been applied to a national assessment of groundwater vulnerability (Nielsen and Lee 1987). This scheme (Goss 1991) combines chemical and physical information on soils and on pesticides and can be used as a management tool to "match" appropriate types and rates of agricultural chemicals to soils, in an effort to keep runoff and residues out of water systems. This is one of the many soil quality assessment questions that could be addressed using pilot data.

Table 5.2-18. Examples of soil assessments.

| | |
|---|---|
| Productivity indices | Berger et al. 1952<br>Storie 1978<br>Kiniry et al. 1983<br>Larson et al. 1983<br>Pierce et al. 1983<br>Gersmehl and Brown 1986<br>Huddleston 1984<br>Huddleston 1982 |
| Erosion Productivity Impact Calculator | Williams et al. 1984 |
| Tilth index | Singh et al. 1992 |
| Changes in soil structure due to cropping systems | Kay 1989<br>Gibbs and Reid 1988,<br>Thomasson 1978 |
| Extent of erosion and land degradation | USDA/SCS RCA Appraisal 1989 |
| Soil leaching potential/groundwater vulnerability | Goss 1991<br>Nielsen and Lee 1987 |
| Sensitivity of soil to acidification from acid deposition | Turner et al. 1986 |
| Land use effects on soil organic matter dynamics | Cole et al. 1989 |
| Organic matter dynamics | Burke et al. 1989 |
| Sustainability index: production per unit soil loss or per unit decline in soil properties | Lal 1991 |
| Sensitivity of soil to degradation | Federoff 1987<br>Yassoglou 1987 |
| Soil ratings for specific uses | USDA/SCS 1983 |
| Global change | Bliss 1990<br>Sombreck 1990 |

## 5.3. Water Quality

### *5.3.1. Introduction*

Agroecosystems are often irrigated and provide a source of drinking water for many Americans. In one sense the agroecosystem is highly stressed from both the use of agricultural chemicals (fertilizer nitrates/phosphate, and pesticides) and the mechanical operations and landscape manipulations associated with food and fiber production. Alternatively, it is the very use of agricultural chemicals and land management that permit farmers to deliver a dependable and plentiful supply of crops for food, fiber and fuel. Agriculture appears to be the largest source of non-point source pollutant loadings to streams and lakes in the United States, and its sediment burden remains a major factor in aquatic habitat degradation. The use of agricultural chemicals and land management practices affect agroecosystem productivity and stress ecological health, including habitat quality, size and diversity of wildlife communities, aquatic populations, and soil biota. The use of agricultural chemicals impacts other connecting ecosystems by exports from the agroecosystem to lakes and streams, wetlands and estuaries, and by leaching to groundwater supplies.

Irrigation is often used during the cropping season to supplement natural rainfall, particularly during drought periods. Irrigation water is obtained from many sources, including farm ponds, lakes, streams, and wells. In North Carolina, irrigation water is obtained primarily from farm ponds that are recharged from wells (personal communication with Ron Snead, Agricultural Engineering Department, North Carolina State University). Chemical applications usually occur during early spring planting of crops and throughout the crop season. Applications of chemicals are made again during the planting of winter cover crops of grain such as winter wheat, rye, oats, and barley. Usually growers will make decisions concerning usage of chemicals, such as herbicides and certain pesticides, prior to or at the time of planting. The original objective of this water quality initiative was to sample farm ponds and wells used for irrigation purposes. However, irrigation practices are scattered throughout the state and many segments may not have irrigated fields. Thus, the principle focus was changed to sample farms ponds and wells

regardless of their use for irrigation purpose. Sampled ponds or wells used for irrigation will be so noted.

The principle objective of the water quality monitoring initiative is to assess the quality of water in farm ponds and wells on a statewide basis (North Carolina Pilot).

### *5.3.2. Sampling Design and Sample Collection*

This effort will involve monitoring and sampling across the entire state of North Carolina. The statewide effort will provide information on water quality in a descriptive sense (e.g. detect or non-detect) for farm ponds and groundwater (existing on-farm wells). Farm ponds and wells will be identified in each sampled segment during the June Enumerative Survey (JES) by NASS enumerators. Information on chemical use at each site is critically needed from the JES to determine sampling and analysis requirements.

Water samples will be collected from farm ponds and wells from either the Hexagon Design (51 segments) or from the NASS Rotational Panel Design (65 segments). Sample collection will be consistent with strategies planned by the ARG. Sampling at each site will be conducted by NASS enumerators in general accordance with guidelines provided in the EPA Region IV SOP Manual (U.S. EPA 1991b). Chemical analyses will be conducted by EPA's Environmental Research Laboratory, Athens, Georgia.

These water samples will be analyzed for specific chemicals such as atrazine, carbofuran, aldicarb, and other selected pesticides (applied to crops such as tobacco, peanuts, corn, and cotton) and nitrates. Testing for pesticide metabolites and sampling of sediment from some farm ponds may be included if resources permit. All agricultural chemicals selected for monitoring will be widely used for crop production in North Carolina. It is not anticipated that any extensive effort will be devoted to determining spatial variability characteristics within farm ponds at this stage, although some limited activity and literature research may be started.

Two sampling approaches will be used for sampling farm ponds: a "boat" sampling method and a "bank" sampling method.

The "Boat" method will utilize a boat to move to three locations on the pond where two samples will be collected at different depths. After compositing the six samples, a sample for analysis will be taken from the composite.

The "Bank" method will utilize a sampling device on a long pole (about 16 feet) which will be extended over the pond while the enumerator stands on the bank. Six samples will be collected from points around the pond; these will be composited, and then a sample for analysis will be taken from the composite.

Either the Hexagon or Rotational Panel sampling frame will be used to select the monitored segments. The actual number will depend on the frame used and the number of segments containing ponds that can be sampled. Of these, half will be selected randomly and used to examine only one pond using the "Bank" technique. In each of the other segments, two ponds will be selected. In each of these ponds, both methods ("bank" and "boat") will be used. In each of the segments where two ponds are utilized, one pond will be selected randomly and replicate samples will be collected by both methods. This design involves a total of 75 ponds and 175 samples, and it provides at least 24 degrees of freedom for each variance component of interest (Table 5.3-1).

Farm pond sampling by boat will require a small jon boat (12 ft.) or canoe and a plumb line or, preferably, a fathometer (depth finder). From a logistical viewpoint and the remote location of some ponds, it could be very difficult for NASS samplers to utilize a boat for sample collection. Therefore a technique for obtaining a representative sample a short distance from the bank is under development. A telescoping pole sampler which will take a 1-liter sample at a depth of 1-foot approximately 15 feet from the bank is being constructed. This prototype will be tested on area ponds to perfect the design. For the pilot study, a comparison of the boat collection and the pole sampler bank collection techniques will be conducted.

**Table 5.3-1.** The anticipated analysis of variance.

| SOURCE | df | Variance component |
|---|---|---|
| Segments | 49 | $\sigma^2_S$ |
| Bank-Only Seg vs Bank & Boat Seg | 1 | |
| Bank-Only Segments | 24 | |
| Bank & Boat Segments | 24 | |
| Ponds (B&B_Segments) | 25 | $\sigma^2_{P(S)}$ |
| Method [1/] | 1 | |
| Method x B&B_Segment | 24 | $\sigma^2_{MxS}$ |
| Method x Ponds (B&B_Segs) | 25 | $\sigma^2_{MxP(S)}$ |
| Residual | 50 | $\sigma^2$ |
| Obs (Bank_Method) | 25 | |
| Obs (Boat_Method) | 25 | |
| Total | 174 | |

[1/] The error term for testing Methods is MxS.

The recommended protocol for sampling ponds from the boat involves composite sampling as follows:

> Three sampling sites within each pond should be selected in accordance with the diagrams in Figure 5.3-1. At each sampling site, samples will be taken in a vertical profile at 1 foot below the surface and at half the depth using a designated sampling device. These samples will be composited for the two depths as well as for the three locations. Wherever possible the boat should first be positioned at the approximate deepest point of the pond (for impounded ponds, this usually will be behind the dam about one fourth the distance of the pond, and, for natural ponds, this usually will be

at the center of the pond). The depth at this point can be determined by using a plumb line (or a depth meter). Each sample will be transferred into a suitably large glass container (plastic containers are not acceptable) which will serve as the compositing vessel. The same procedure will be followed at the remaining locations using the same compositing vessel. There should be at least two gallons of water in the vessel after all sites have been visited. The composited sample will be mixed well, and three 1-qt subsamples will be poured off. The samples will be placed on ice immediately for transport to the analytical laboratory or holding facility.

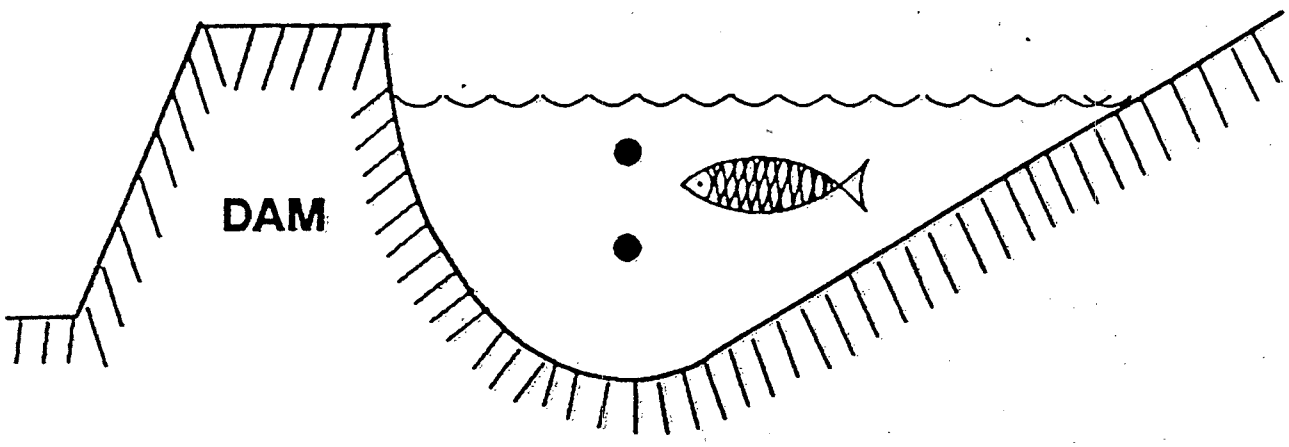
The recommended protocol for "bank" sampling of ponds is being developed.

For well sampling, the following protocol is to be followed:

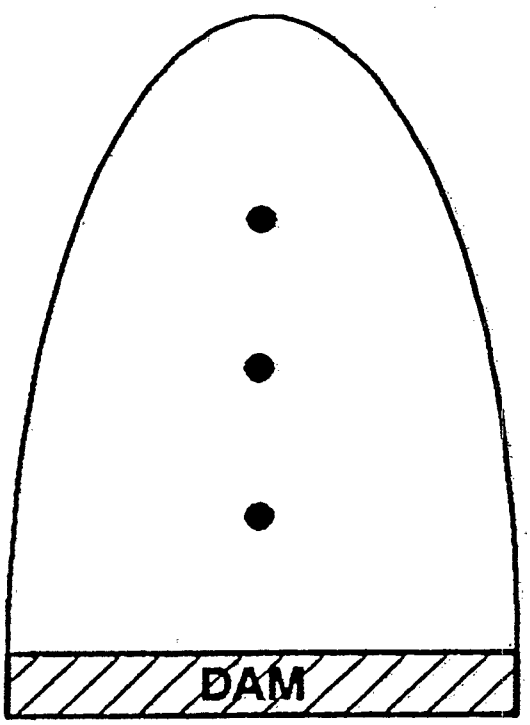
Locate a faucet at a nearby wellhead. The well first must be purged by opening the cold-water faucet to remove stored water, usually requiring at least five well volumes of water before a sample is collected. The volume of water to purge depends on the storage/pressure tank volume. A complete exchange of the volume of water in the tank is required to collect a representative sample of ground water. About 30 minutes is a reasonable time estimate if the faucet is located behind the storage tank, or about five minutes if the faucet is located between the storage tank and pump motor and/or plumbing entering the well. During the purging process, measurements of temperature, conductivity and pH can be made to determine if the stored water is removed from the system. When the measurement parameters stabilize or when the designated purging time has elapsed, a sample can be collected directly into a one-quart glass bottle and placed on ice immediately for transport to the analytical laboratory.

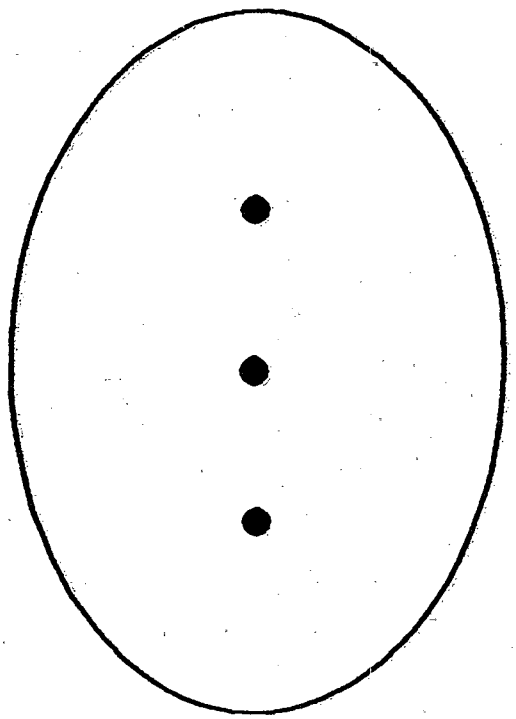
### *5.3.3. Essential Complementary Data*

Information on chemical use on each segment is critically needed from the NASS JES to determine sampling and analysis requirements. A farm pond (identify if used for irrigation purposes) and well will be located in each segment for sampling purposes.




Vertical profile sampling



Constructed Impoundment

Natural Impoundment

Figure 5.3-1. Sampling Design for Farm Pond.

### *5.3.4. Logistics*

Sample collection and transport to analytical laboratory:

All samples will be collected by NASS, stored on ice immediately, and shipped in insulated containers to Athens-ERL for residue analysis. Samples will be shipped by fastest possible means the same day as collected. If unforeseen events make same day shipment impossible, the samples will be stored under refrigeration at 34-40°F (2-4°C) until shipment. Sampling must be scheduled so that samples will not be stored by the collector over the weekend. Samples will be stored at 2-4°C at the laboratory until analysis.

### *5.3.5. Quality Assurance*

Sample Collection:

All water samples must be properly (i.e. according to protocol) collected in 1-qt amber glass bottles (Athens will supply sampling containers). Fortified samples will be held under identical storage conditions as field-collected samples and analyzed at regular intervals to assess storage stability. Ten percent of field samples will be analyzed in duplicate. Outliers will be analyzed in triplicate, if possible.

Prior to the collection of field samples, duplicate spiked samples will be run at several concentrations to determine method accuracy and precision and to establish lower limits of detection. During the analysis period, fortified recoveries will be analyzed as dictated by the situation, but not less than one set per month. Spiking levels and range will be determined by that time.

One reagent blank will be run each time samples are extracted (sample set). Standard instrument calibration curves will be prepared at least once each instrument operating day. Individual laboratory log books and instrument log books will be kept current and reviewed by

the project officer on a regular basis. Analytical standards will be obtained from the EPA repository at Research Triangle Park, NC or check-analyzed against an EPA standard if obtained from another source.

Data Quality Objectives (DQO) will be established prior to the generation of sample data. Approved EPA methodology will be utilized whenever possible and standard operating procedures (SOP) referenced or written as needed. Quality control activities are a key component for assuring high quality data. To minimize systematic bias attributable to laboratory techniques and to ensure objectivity in measurements, samples will be analyzed in random order. Such randomization of samples helps ensure that observed trends are actually due to field responses.

Laboratory Analyses:

All analytical support for this effort will be conducted at EPA's Environmental Research Laboratory, Athens, Georgia. Analysis of pesticides will require analytical sensitivities in the low parts per billion range in extractions from both water and sediment. The analysis requires production-line efficiency for large numbers of samples with multiple extractions. Depending on the sample type and the test compounds, samples will be extracted using solid phase, liquid-liquid, ultrasonic, or Soxhlet extraction techniques. Also, depending on test compounds, the analyses of the extracted residue will be conducted by gas chromatography utilizing electron capture (ECD), flame photometric (FPD), nitrogen-phosphorus (NPD), or Hall electrolytic conductivity (Hall ECD) detection systems or high pressure liquid chromatography utilizing post column reaction (PCR) and ultraviolet (UV) detection systems.

Depending upon available resources, residue analysis at Athens-ERL may include atrazine, carbofuran, aldicarb, other selected pesticides, metabolites and nitrate.

### *5.3.6. Metadata Requirements*

Metadata will include methods of analysis, reporting units, data formats, and pertinent comments by samplers or laboratory personnel.

### *5.3.7. Data Analysis and Integration*

The result of this effort will be a database with generally the same design characteristics as other parameters being examined within the Pilot. Standard statistical techniques will be applied to summarize the data in meeting Program objectives.

### *5.3.8. Research Goals and Application*

Assess quality of irrigation water supplied by farm ponds and wells on a statewide basis in the North Carolina Pilot.

## 5.4. Land Use and Cover

### *5.4.1. Introduction*

A concept central to the field of landscape ecology is that the changing spatial structure of a landscape affects the flow of energy, materials, and organisms across its components. Agricultural landscapes, largely as a result of human activity, are characterized by spatial and temporal patchiness on many scales. There are annual changes in agricultural land use, as well as decades-long processes as land cycles between agriculture and other uses. One must consider, for example, the influence of a hedgerow on an adjacent field, as well as the cumulative effects of agricultural systems on the habitat of far-ranging species.

Changes in land use patterns, which may represent significant ecological change in their own right, may also foreshadow further ecological change in agricultural landscapes. For example:

- An increase in chemical-intensive crops might affect water quality in surrounding areas.
- Removal of hedgerows and shelterbelts may lead to increased soil erosion.
- Changes in the amount and spatial structure of non-cropped land areas in the landscape may affect populations of plants and animals which 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.
- Degradation of soil or water quality may lead to the abandonment of cropped land.

The ARG has defined two closely related assessment endpoints to 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 assessment endpoint.

- *Landscape structure*: a more comprehensive analysis of the spatial structure of the various components of agricultural landscapes. This research effort is described in section 6.2.

For EMAP, the agricultural landscape is comprised of several broad categories of land use, including the land area 1) in cropland, by crop; 2) in permanent pasture, set-aside programs, or fallow; 3) in use for managed animal production; 4) in farm ponds or other water; 5) in non-cropped areas, such as hedgerows, woodlots and grassed waterways; and 6) devoted to buildings and paved areas.

For the 1992 Pilot, land use will be monitored at multiple scales using:

- NASS area frame materials (broad spatial and temporal scale for all land).
- Thematic Mapper data (medium spatial and temporal scale for all land).
- Survey data collected by NASS (fine spatial and medium temporal scale for cropped land).
- Interpretation of aerial photographs (fine spatial and medium temporal scale for non-cropped land; see section 6.2 *Landscape Structure*).

### *5.4.2. Data Acquisition*

#### *Area Frame Material*

The NASS area frame (Cotter and Nealon 1987) provides complete coverage of the conterminous United States and Hawaii. Sampling frames are developed by state and are currently updated every 15-20 years. The components of the area frame are summarized below. Detailed information, including the strata used for the North Carolina frame, may be found in the *Design and Statistical Considerations* section (Section 3) of this document, and in Cotter and Nealon (1987).

- **Strata:** A state's land area is stratified according to intensity of cultivation. Stratification is performed by county.

- **PSU**: Strata are further subdivided into primary sampling units (PSU). The size of the PSU's varies by stratum, but is 15-20 square kilometers for most agricultural strata. A random sample of PSU's is drawn to represent each stratum. PSU boundaries are digitized by NASS.

- **Segment**: All selected PSU's are further subdivided into segments of approximately 2.6 square kilometers each. One segment is selected at random from each selected PSU. The resulting set of segments comprise the NASS sample.

The NASS stratification of land area provides a framework in which to analyze long-term changes in land use patterns over large geographic areas. For the 1992 pilot, a procedure for creating a geographic information system (GIS) coverage based on the NASS strata will be developed and tested using the North Carolina area frame. The current frame for North Carolina was developed in 1978 and will serve as a baseline against which future frame changes in North Carolina will be measured. Strata maps for the state can be created by combining county strata maps using GIS techniques. Because the strata represent very broad categories of land use intensity (*e.g.*, 15-50% agriculture), these maps will directly reflect only large changes in agricultural land use intensity. Table 5.4-1 summarizes the steps needed to create an ARC coverage of the NASS area frame.

***Thematic Mapper Data***

The State of North Carolina has developed ARC coverages of land use and cover for the Albemarle-Pamlico watershed, which covers a large portion of northeastern North Carolina and southeastern Virginia (Khorram et al. 1991). The coverages are based on Thematic Mapper data collected during the winter of 1987-88. The classification, performed at North Carolina State University as part of the Albemarle-Pamlico Estuarine Study, used a hierarchical classification system as shown in Table 5.4-2.

**Table 5.4-1.** Steps to convert NASS area frame to ARC format.

| *Step* | *Target Completion* | *Actual Completion* |
|---|---|---|
| 1) For each county, NASS Area Frame Division registers PSU map to latitude / longitude. QA checks applied by NASS. | Already complete | -- |
| 2) For each county, NASS Area Frame Division converts PSU map from internal to DLG format. | 8/30/91 | 9/30/91 |
| 3) DLG files shipped to ARG with paper map and PSU area listing for each county. | 10/30/91 | files: 9/30<br>areas: 10/30 |
| 4) DLG maps converted by ARG to ARC format and strata map for each county produced. If a county does not convert cleanly, the county map is plotted on paper and returned to NASS for clarification. | 12/15/91 | 1/15/92 |
| 5) ARC county coverages edge-matched by ARG to provide seamless PSU map for the state. QA check of boundaries with other coverages of state and county borders. | 5/15/92 | |
| 6) Dissolve PSU boundaries between like strata to provide a seamless strata map for the state. | 5/15/92 | |
| 7) Provide complete documentation of procedure used to create coverages. Also document all GIS files created according to ASTM standards. | 6/15/92 | |

These data have been purchased by the EMAP-Landscape Characterization Group at the request of the ARG. The ARG and the Landscape Characterization Group will cooperate in the use and analysis of these data. For the 1992 Pilot, the ARG will use these data to summarize land cover, at the Level 1 classification, for the portions of the Albemarle-Pamlico watershed within North Carolina. These data will also be used for research in landscape structure indicators for large geographic areas (see Section 6.2).

**Table 5.4-2**: Classification system for Albemarle-Pamlico watershed land cover data.

| *Level 1* | *Level 2* |
|---|---|
| Urban or Built-Up | Low density<br>Medium density<br>High density |
| Agriculture / Grassland | Agriculture/grass fields<br>Disturbed land |
| Forest Land | Hardwood<br>Pine<br>Mixed Pine / Hardwood |
| Shrub / Scrub | Low Density Vegetation |
| Water | Water |
| Wetland | Bottomland Hardwood<br>Riverine Swamp<br>Evergreen Hardwood / Conifer<br>Atlantic White Cedar<br>Low Pocosin<br>Low Marsh<br>High Marsh |
| Barren Land | Sand |
| Other | Undetermined |

### *June Enumerative Survey (JES) Data*

Land use data for all selected sample segments are collected annually by NASS during the June Enumerative Survey (JES). The entire land area of the segment is classified into one of the categories shown in Table 5.4-3. As described in the *Design and Statistical Considerations* section (Section 3) of this document and in Cotter and Nealon (1987), these values are expanded to give land use estimates within each stratum and for the entire state. It is anticipated that JES data for North Carolina will be available from NASS in July 1992. The entire North Carolina JES sample will be utilized to calculate land cover estimates. Although NASS typically

maintains JES data in SAS datasets, the precise form and manner in which these data will be received and analyzed by the ARG is still to be determined. Each JES record must be identified by county and PSU number.

**Table 5.4-3.** NASS JES land use classification.

| Land Use Classification |
|---|
| Cropland, by crop |
| Permanent pasture |
| Pastured cropland |
| Idle cropland |
| Occupied farmstead or dwelling |
| Other (woods, waste, roads, ditches, etc.) |

These data provide extensive information about the land used for agricultural production and very little information about other components of the landscape. Consequently, these data will be used primarily to analyze changes in land used for agricultural production. Steps to acquire JES data are shown in Table 5.4-4.

**Table 5.4-4.** Steps to acquire JES data.

| *Step* | ***Target Completion*** | ***Actual Completion*** |
|---|---|---|
| 1) ARG develops survey instrument with NASS. | 9/30/91 | 9/30/91 |
| 2) NASS obtains OMB approval. | 3/30/92 | |
| 3) JES data collected by NASS enumerators. | 6/15/92 | |
| 4) JES data released to ARG. | 7/15/92 | |

### *5.4.3. Logistics and Quality Assurance*

No special field sampling is required. Some QA aspects are discussed under data acquisition. Standard NASS QA procedures will be used during administration of the JES.

QA procedures used by NASS for area frame development are documented in Cotter and Nealon (1987).

Procedures used in developing the Albemarle-Pamlico database are documented in Khorram et al. (1991).

These documents are available at the ARG headquarters in Raleigh, NC.

### *5.4.4. Metadata Requirements*

#### *GIS Coverages*

All GIS coverages will be documented in accordance with ASTM Draft Proposed Specifications for Meta-Data Support in Geographic Information Systems (August 1991), which has been adopted as a standard by the GIS Team of the EMAP Information Management Task Group. The manner in which these data will be stored has not been determined.

#### *JES Data*

For each data element, at least:

Name
Brief description
Data type (integer, real, character)
Measurement type (categorical, nominal, ordinal, interval, ratio)
Definition of categories (for categorical and nominal data)
Units (for ordinal, interval and ratio data)
Data collection method
Error information

### *5.4.5. Data Analysis and Integration*

Figures 5.4-1, 5.4-3 and 5.4-4 show the flow of data from collection through analysis to development of the final reporting product.

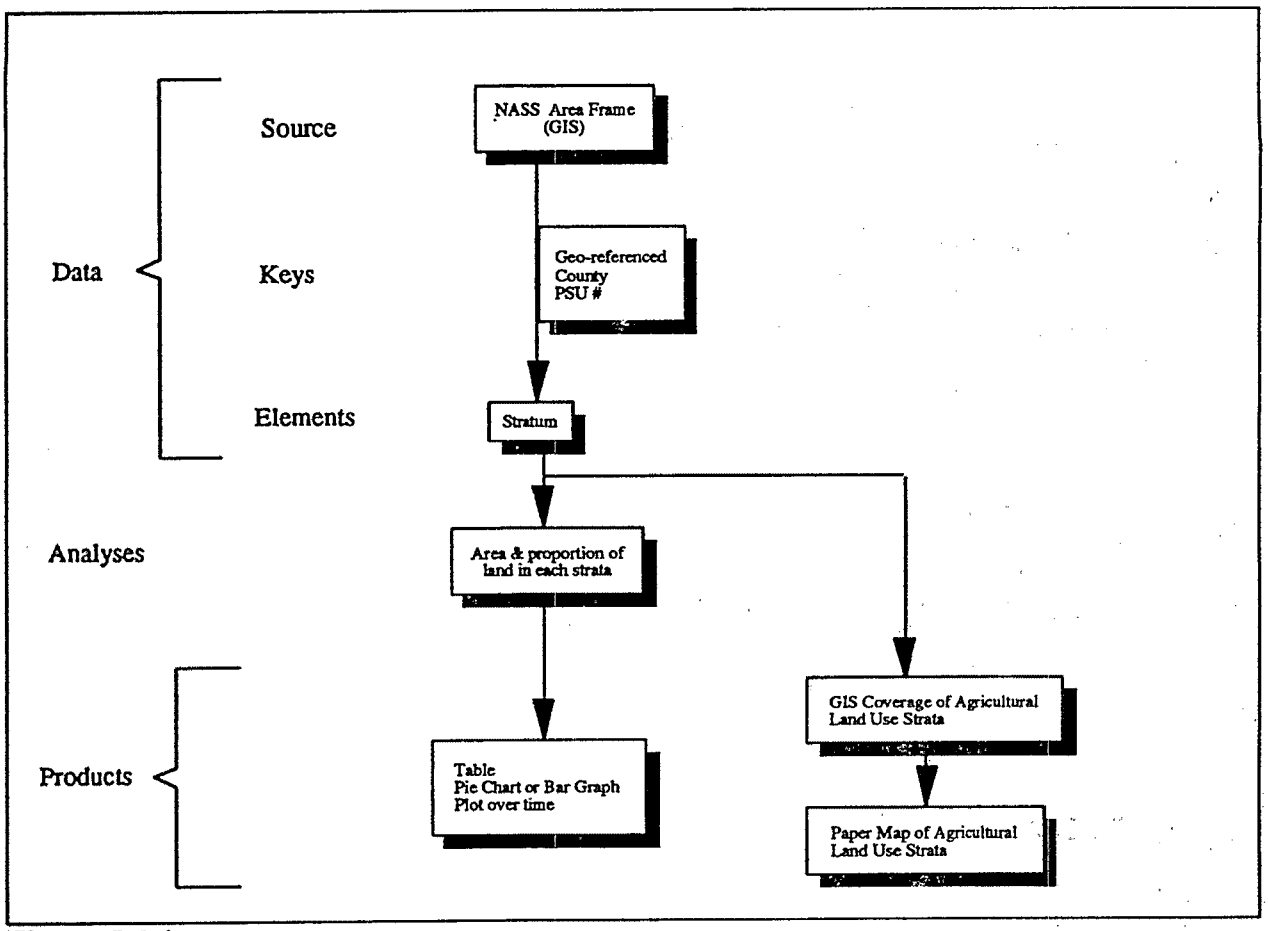



**Figure 5.4-1.** Use of NASS Area Frame data.

Figure 5.4-1 shows how the NASS Area Frame data will be utilized. An indicator of *Agricultural Land Use Intensity*, based on the NASS stratification process, will be calculated for the state of North Carolina. The frame will also be used to develop a GIS coverage of the NASS strata which will be used as a data layer in other GIS analyses.

**Indicator 1) Agricultural Land Use Intensity**: report area and areal proportion of land in each agricultural land use intensity category (stratum).

*Source of data:* NASS area frame

*Summary statistic for segment:* not applicable

*Sampling method:* entire state covered; not sampled

*Variance structure:* base map accuracy, digitizing, GIS conversions

*Trend to be detected:* long-term (15-20 years) changes in land use

*Base period:* 1978, year of current area frame for North Carolina

*Nominal and Subnominal:* not appropriate

*Note:* Figure 5.4-2 is a preliminary pie chart showing the area and proportion of land in each of the eight NASS strata for North Carolina.

Figure 5.4-3 shows how Thematic Mapper (TM) land cover data will be used to develop indicators of overall land cover. For the 1992 Pilot, only the North Carolina portion of the Albemarle-Pamlico watershed will be analyzed. Indicators of *Overall Land Cover* and *Overall Land Cover Diversity* will be calculated. The GIS coverage of the NASS area frame will be used to stratify the TM data.

**Indicator 2) Overall Land Cover:** report estimated area and areal proportion of land for each Level 1 land cover category (Table 5.4-2) for each stratum and for the North Carolina portion of the Albemarle-Pamlico watershed.

*Source of data:* TM data & NASS area frame

*Summary statistic for stratum:* hectares of land in each TM category

*Sampling method:* entire stratum covered; not sampled

*Variance structure:* measurement, digitizing, classification, overlay

*Trend to be detected:* changes in land cover

*Base period:* 1987-88, date of TM data acquisition

*Nominal and Subnominal:* not appropriate

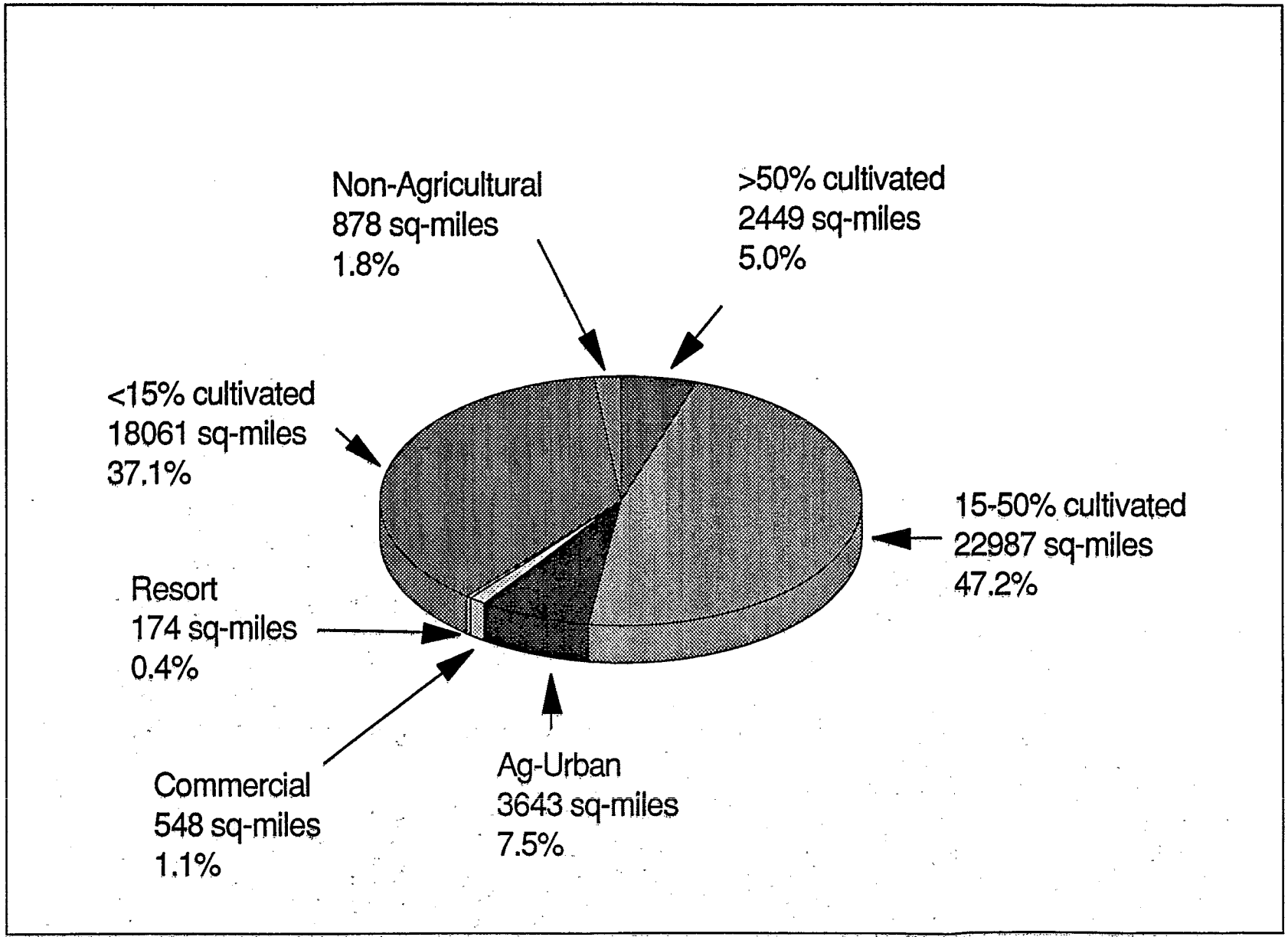



**Figure 5.4-2.** Preliminary pie chart showing the area and proportion of land in each of the eight NASS strata for North Carolina (USDA,NASS 1991d).

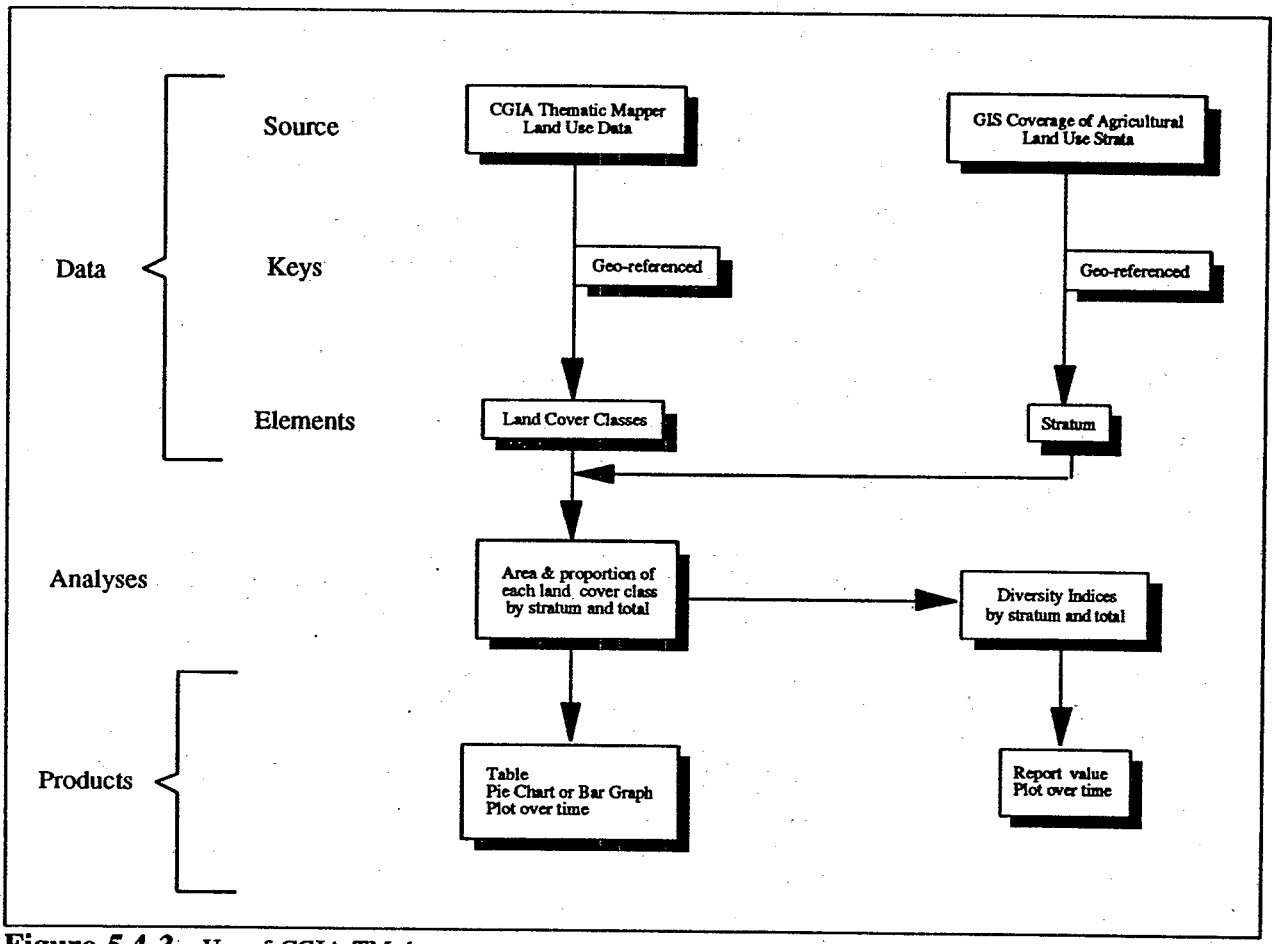



**Figure 5.4-3**. Use of CGIA TM data.

**Indicator 3) Overall Land Cover Diversity:** use *Overall Land Cover Proportions* to calculate a diversity index for each stratum and for the North Carolina portion of the Albemarle-Pamlico watershed.

*Source of data:* TM + NASS area frame

*Summary statistic for stratum:* proportion, $p_i$, of land in each Level 1 TM category $i$

*Sampling method:* entire stratum covered; not sampled

*Variance structure:* measurement, digitizing, classification, overlay

*Calculations:*

$$\textit{Simpson's Index}$$
$$D = \Sigma p_i^2$$

$$\textit{Shannon-Wiener Index}$$
$$H = -\Sigma p_i \log(p_i)$$

$$\textit{Shannon-Wiener Eveness Measure}$$
$$E = \frac{H}{H_{max}} = \frac{H}{\log(\textit{number of categories})}$$

*Trend to be detected:* changes in overall land cover diversity

*Base period:* 1987-88, date of data acquisition

*Nominal and Subnominal:* unknown

Figure 5.4-4 summarizes the development of several indicators using JES data. These data will be used to calculate indicators of *Production Land Use* and *Production Land Use Diversity. Production Land* includes all but the other (wood, waste, etc.) land use categories on the JES. The values of these indicators will be reported and tracked over time. The entire North Carolina JES sample will be utilized to calculate these indicators.

**Indicator 4) Production Land Use**: report estimated total area and areal proportion of production land for each JES land use category (Table 5.4-3) for each stratum and for the entire state.

*Source of data:* JES

*Summary statistic for segment:* acres of land in each JES category

*Sampling method:* see *Design and Statistical Considerations*, Section 3

*Variance structure:* see *Design and Statistical Considerations*, Section 3

*Trend to be detected:* annual changes in production land use

*Base period:* 1991

*Nominal and Subnominal:* not appropriate

**Indicator 5) Production Land Use Diversity**: use *Production Land Use Proportions* to calculate a crop diversity index for each stratum and for the entire state.

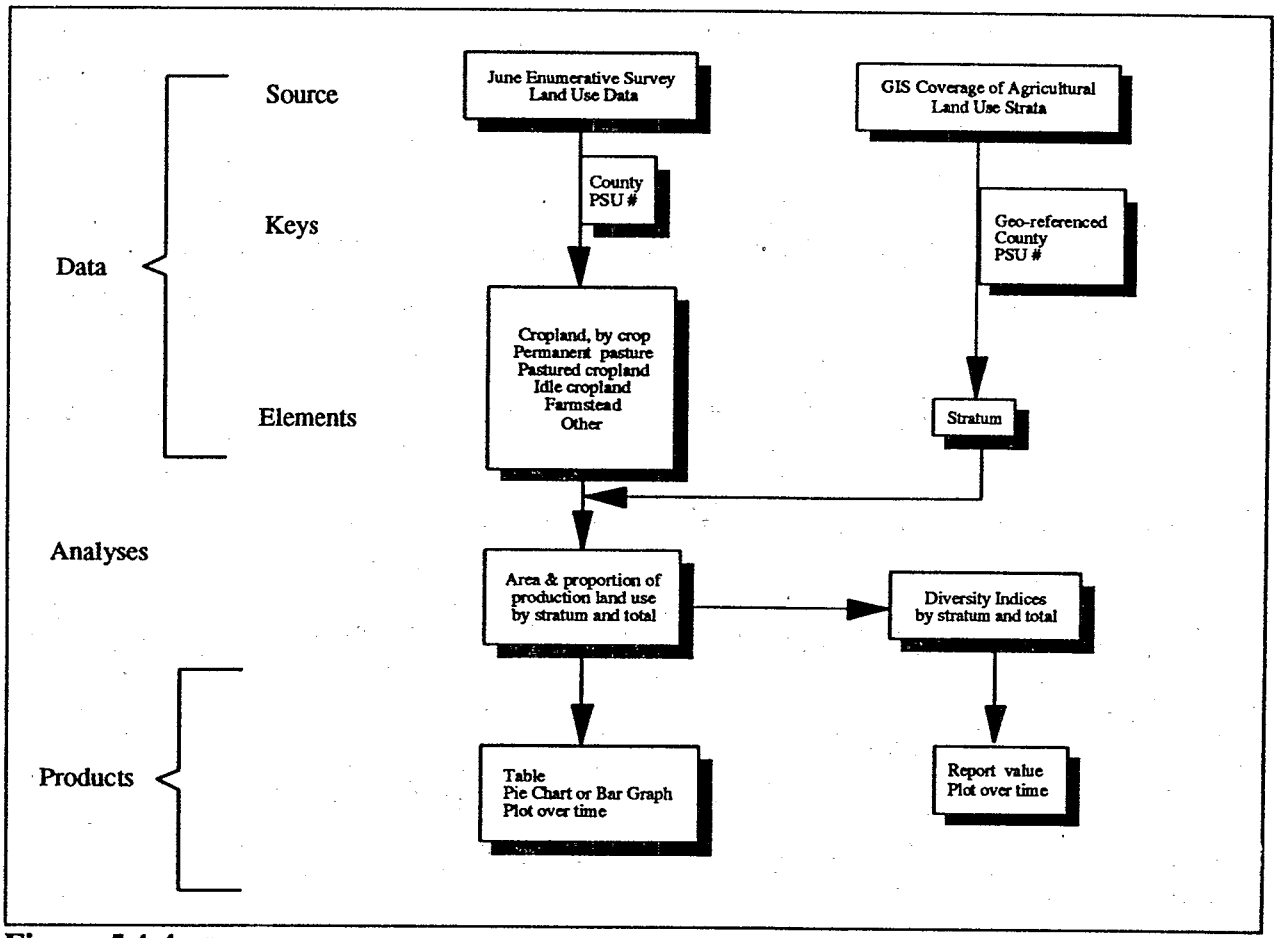



**Figure 5.4-4.** Use of NASS JES data.

*Source of data:* JES

*Summary statistics for segment:* proportion, $p_i$, of land in each JES category

*Sampling method:* see *Design and Statistical Considerations*, Section 3

*Variance structure:* see *Design and Statistical Considerations*, Section 3

*Calculations:* same formulae as *Overall Land Cover Diversity*

*Trend to be detected:* annual changes in production land use diversity

*Base period:* 1991

*Nominal and Subnominal:* unknown

### *5.4.6. Research Goals and Applications*

*Error Structure*

The error structure of the land use indicators must be understood and quantified in order to determine the magnitude of land use changes which may be detected by these approaches.

The error structure of production land use data collected during the NASS JES is known. It has been documented by NASS (Cotter and Nealon 1987) and is described in the *Design and Statistical Considerations* section (Section 3) of this document.

Quality assurance procedures and error rates for the Albemarle-Pamlico land cover data are described in Khorram et al. (1991). This document contains error matrices for classification of the satellite data based on "ground truthing" of a sample of one acre sites within the study region. "Ground truthing" for this study was carried out using 1:58,000 scale National High Altitude Photography images. The error matrices provide an estimate of the accuracy of land cover classification.

The NASS area frame for North Carolina was developed using 1/2 inch : 1 mile scale county highway maps as base maps. Accuracy assessment of this material may be difficult. Errors in the frame arise from many sources, including errors in the base map, errors in the digitization process, and errors in registration. More work is required in determining how to quantify the error associated with the area frame. Consultation with members of the NASS Area Frame Section, the EMAP GIS Team, and the EMAP Landscape Characterization Group will be necessary. Recent changes at NASS, including increased automation of frame development, should simplify accuracy assessment of new area frames.

*Indicator Correlation*

One goal of the pilot program is to determine if selected indicators are highly correlated and possibly redundant. For example, land use cover may be correlated with surface water quality. The monitoring program might be streamlined by eliminating redundant indicators. The data from the 1992 pilot will be analyzed to determine if any of the land use and cover indicators are correlated with any of the other indicators. Tier III research might be required to further study any unexpected correlations among indicators.

## 5.5. Agricultural Chemical Use

### *5.5.1. Introduction*

Agricultural chemical use is a quantitative measure of rates and spatial and temporal distributions of chemicals applied to agroecosystems.

Objectives:

- Determine actual use of pesticides and fertilizers
- Use as a surrogate measure for pest density and pest spectrum
- Use in risk analysis of potential ecological impacts of agrichemical use

### *5.5.2. Data to be collected by NASS (See Appendix 5)*

- Type, rate and frequency of fertilizer use
- Type, rate and frequency of pesticide (insecticide, fungicide, nematicide) use
- Type, rate and frequency of herbicide use
- Crop treated
- Number of acres treated
- Mode of application
- Time of application

### *5.5.3. Essential Complementary Data*

- Costs of chemical inputs

- Chemical grouping (type of compound) for each chemical (other grouping properties may include persistence, toxicity, chemical formulation, and mode of action)

- Spectrum of plants and pests against which the herbicides and pesticides are effective; for which crops and pests they are registered in each state

- Reason grower applied a specific compound

### *5.5.4. Logistics*

- See NASS survey logistics

### *5.5.5. Quality Assurance*

- See NASS survey logistics

### *5.5.6. Metadata Requirements*

- Trade name of compound
- Formulation
- Manufacturer of compound

### *5.5.7. Data Analysis and Integration*

1. Classify pesticides into ecologically meaningful groups such as persistence, toxicity, chemical formulation, mode of action, and spectrum of pests affected

   - Classes need to be identified.

   - Data management strategies need to be worked out to classify the many different individual compounds that will be present in the raw data.

2. Frequency distribution of fertilizer and pesticide use (proportion of acres treated with a certain class of pesticide and fertilizer)

3. Spatial distribution of pesticide and fertilizer use

### *5.5.8. Research Goals and Applications*

1. Nontarget effects on soils and biological communities
   Data currently collected by the National Agricultural Statistics Service (USDA 1991) can also be used for this assessment.

Examples:

- What proportion of herbicides used are highly degradable?
- What proportion are highly persistent?
- What proportion of insecticides used are organophosphates?
- What proportion are pyrethroids?

2. Nontarget effects on water resources

- Relate soil leaching and runoff potential to the leaching and runoff potential of the specific pesticide (Goss 1991). Use to calculate relative overall potential for leaching and runoff.

- Present as frequency of land area with high, medium or low potential for pesticide leaching or runoff.

- Because specific chemicals will be related to the specific soil of the treated area, EMAP data, which is taken at the same sample point, would be the best data for this assessment.

3. Surrogate measure for incidence of specific weeds or pests

- Many pesticides are registered and targeted for management of a specific weed, insect or pathogen. The amount of specific pesticides applied may, therefore, serve to indicate which weed/pest problem either was or were expected to be a problem in a region during a given growing season. Data currently collected by the National Agricultural Statistics Service (USDA 1991) can also be used for this assessment.

# 6. Description of Specific Research Endpoints for the Pilot Project

## 6.1. Soil Biological Health

### *6.1.1. Goals and Approach*

Free-living nematodes comprise up to 90% of the total nematodes in agricultural soils (Stinner and Crossley 1982) and are a group of soil fauna that have promise for use as an indicator of pollution exposure and the restoration capacity of soil ecosystems (Schouten et al. 1990). Nematodes have the following attributes that make them useful as ecological indicators (Freckman 1988).

- Nematodes are small with short generation times, allowing them to respond quickly to changes in food supply; they are ubiquitous, even in polluted or disturbed areas; they are frequently the last animals to die.

- Nematodes have the ability to survive desiccation and revive with moisture.

- Populations are relatively stable with soil, thus any change is viewed as the result of an environmental perturbation.

- Perturbation of nematode populations usually reflect a change of trophic structure.

- Trophic, or functional, groups can be separated easily, primarily by anterior structures associated with various modes of feeding (Yeates and Coleman 1982, Freckman 1988). Therefore, species identification is not necessary and the cost associated with identification is relatively small.

- Abundance and size of nematodes makes sampling easier and less costly than for other microflora and fauna.

Functional groups of nematodes are present in three positions of food webs in soil. Plant-parasitic nematodes are herbivores, feeding on plant roots and are, therefore, consumers of primary production. Bacterivores and fungivores consume bacteria and fungi (including mycorrhizae), respectively, and are, thus, involved directly with decomposition and nitrogen mineralization (Parmelee and Alston 1986; Seastedt et al. 1988; Sohlenius et al. 1988; Moore and de Ruiter 1991). Omnivores add "connectedness" to the food web (Coleman et al. 1983) by feeding on more than one food source, including bacteria, flagellates and amoeba. Predaceous nematodes feed upon all the other functional groups of nematodes (Moore and de Ruiter 1991).

### *6.1.2. Data to be Collected*

Populations of nematodes in soil will be quantified by five trophic (functional) groups: 1) plant parasites, 2) bacterivores (microbivores), 3) fungivores, 4) omnivores, and 5) predators (Yeates 1971). Numbers of nematodes in each trophic group will be counted in 500 $cm^3$ soil (Section 5.2.4) and transformed to numbers per kg dry soil to standardize values among soils with different soil moistures (Section 6.1.4).

### *6.1.3. Essential Complementary Data*

Various soil characteristics influence populations of nematodes. Soil parameters measured will include organic carbon, exchangeable calcium, exchangeable sodium, pH, electrical conductivity, soil texture, and gravimetric soil moisture (see Section 5.2). In addition, data concerning 1) application of nematicides, by tradename and formulation, within the past 2, 2-4, or 4-12 months; 2) crop(s) planted; 3) cropping history; and 4) tillage practices will be obtained from the NASS Questionnaire (see Appendix 5). The NASS Questionnaire will also include questions regarding applications of herbicides and pesticides that may be used to interpret observed community patterns of nematodes (Section 6.1.7).

### *6.1.4. Logistics*

**Sample collection.** Only soil sampled from the Rotational Plan Design will be analyzed for nematode populations. An autumn sampling period is proposed, following cultivation of crops harvested in the fall. Populations of bacterivorous and fungivorous nematodes are favored at this time because 1) crop residues are incorporated into soil by cultivation, and 2) temperatures are favorable (15-20 C) (Stinner and Crossley 1982). Samples should not be collected from saturated soils, otherwise anaerobic conditions would develop in the plastic bags during storage and transport. Anaerobic conditions could decrease the estimates of nematode populations.

Although there are few quantitative studies describing the spatial patterns of bacterial-feeding nematodes (McSorley et al. 1985), populations are probably aggregated around plant roots and organic debris in a manner similar to plant-parasitic nematodes. Therefore, ridges, furrows, and plant rows should be sampled with equal probability within a field. Because nematode populations are aggregated spatially, soil samples will be collected using a systematic design described in Section 3 and Appendix 6. Except for fields that are chosen for two composite samples, 20 cores (2-cm diameter), taken to 20-cm depth, will be collected along a diagonal transect described in Section 3.3.2, across a five-acre area, chosen at random, and pooled as one composite sample for estimation of field populations. After all cores have been collected in a bucket and gently (excessive pressure or abrasion will damage or kill nematodes) homogenized, a 550-$cm^3$ (500- ml beaker filled to the edge) subsample will be transferred to a 4 x 2 x 12 inch plastic bag. The bag will be closed with a pre-labeled wire tag with the appropriate identification code and stored in an insulated container or at temperatures < 30 C (Barker 1985b) until mailed, to avoid temperatures that may affect estimates of nematode populations. All equipment necessary for collection of the samples will be included in the enumerator kit (Table 5.2-9 in Section 5.2).

Samples will be mailed using Federal Express (call 1-800-238-5355 for pickup) either the day of sampling or the following morning to the enumeration laboratory (ATTN: Kitty Kershaw or Ken Barker, 840 Method Rd Unit II, Raleigh, NC 27606). Prior to mailing, the soil sample

should be placed in a padded (with bubble wrap) envelope, which is pre-addressed and postage-paid to the enumeration laboratory. Methods for transport of samples to the enumeration laboratory were tested in the December 1991 nematode survey in North Carolina. There were no significant differences in nematode populations when mailed or carried to the analysis laboratory. There was also no significant effect of mailing an ice pack with the soil sample.

Samples should be mailed between Monday and Thursday so they arrive in the enumeration laboratory on a weekday. Otherwise, the laboratory should be notified (919-515-3330) so that samples can be placed in appropriate environmental conditions immediately upon arrival, rather than be stored in the post office or postal truck over a weekend. As samples are received by the enumeration laboratory, the date of receipt will be logged on the list of identification codes and sent to the laboratory before sampling is started. Samples will be stored at 15 C and processed within 14 days of receipt.

**Laboratory analyses.** Nematodes will be extracted from 500 $cm^3$ soil using a semiautomatic elutriator followed by sucrose centrifugation (Barker 1985a). Elutriation was chosen as the extraction method because this process allows for the extraction of both live and dead nematodes, which permits use of samples that may have been mishandled before reaching the enumeration laboratory. A dissection microscope will be used as an aid to identify and enumerate nematodes in soil by trophic group; compound-light microscopy will be used to confirm uncertain identifications. The remaining 50 $cm^3$ soil will be weighed, both moist and oven-dry (90 C for 48 hr), to determine the dry weight per $cm^3$ soil. Numbers of nematodes in each trophic group will be standardized as numbers per g or kg and per $m^2$ (assuming 20-cm core depth and 2 cm diameter) to permit meaningful comparisons with other methods and reports. Statistical analyses will be conducted on non-transformed population data. A log $(x+1)$ transformation will be used if required to normalize the variance.

### *6.1.5. Quality Assurance*

**Samples.** Samples will be shipped in pre-labeled containers with unique sample numbers and logged on an inventory sheet as received by the enumeration laboratory as described in Section 5.2.5. Duplicate samples will be submitted to the enumeration laboratory for determination of within laboratory and within field variability (Appendix 7). The variability will be compared to expected ranges, standard deviations and % coefficients of variation established from preliminary surveys conducted in 1990 and 1991 (Tables 6.1-1, 6.1-2). It is impossible to submit known blanks with the field samples because of complex inoculation, handling and storage procedures involved in handling biological organisms.

**Laboratory analyses.** Because the indicator encompasses many genera and trophic groups, it is not possible or realistic to determine the extraction efficiency for each individual species. Extraction efficiencies for an elutriator can range from 30-60% depending on the type of soil, the screen, and the amount of organic matter. Alternatively, an average extraction efficiency for plant-parasitic nematodes will be reported, to provide an efficiency of the extraction method for the laboratory chosen for enumeration services (Section 6.1.8).

Nematodes from 10% of the submitted samples will be preserved in formalin-aceto-alcohol (FAA) solution (90 ml of 50% ethanol, 5 ml of glacial acetic acid, and 5 ml of 37% formaldehyde) and stored at room temperature (Daykin and Hussey 1985). The preserved samples will be kept for one year and utilized if information about genera within trophic groups is needed.

The data from the nematode enumeration laboratory will be sent as a hardcopy to the ARG information manager who will arrange to have the data key-punched at the North Carolina Agricultural Statistics Division (Raleigh) of NASS. After the data are entered into the computer, they will be combined with the other soils data described in Section 5.2.5. Necessary transformations will be performed by the ARG information manager before the data are

**Table 6.1-1.** Reporting Units, Precision and Expected Ranges for Nematode Populations (December 1991)

| Parameter | Reporting units[c] | Reporting precision[a] | Expected range (median)[b] |
|---|---|---|---|
| PLPAR[d] | no./kg | 1.0 | 0 - 3697 (500.5) |
| BACT[e] | no./kg | 1.0 | 53 - 1884 (483.5) |
| FUNG[f] | no./kg | 1.0 | 0 - 541 (102.5) |
| OMNI[g] | no./kg | 1.0 | 0 - 57 (0) |
| PRED[h] | no./kg | 1.0 | 0 - 208 (40) |
| WT_VOL | g/cc | 1.0 | 0.33 - 1.06 (0.90) |

[a] Number of significant decimal places
[b] Expected concentration ranges in reporting units for soil samples, based on the 1st, 95th, and (50th) percentiles of data collected from the December 1991 survey; n = 122 for nematodes and n = 80 for WT_VOL.
[c] All values expressed on an oven-dry soil weight basis.
[d] Plant-parasitic nematodes
[e] Bacterivorous nematodes
[f] Fungivorous nematodes
[g] Omnivorous nematodes
[h] Predaceous nematodes

integrated into the larger NASS data set at the North Carolina Agricultural Statistics Division (Raleigh).

### *6.1.6. Metadata Requirements*

In addition to data used for analysis, metadata will be recorded to permit future interpretation of the database. Metadata will include methods of analysis, reporting units, whether data are integers or characters, name of analytical laboratories, and comments recorded during sampling or processing procedures (Table 6.1-3).

### *6.1.7. Data Analysis and Integration*

Several indices will be computed for the nematode community in each soil sample. The fields will be compared using cluster analysis (Hodda 1986) to test the indices for their ability

**Table 6.1-2.** Data Quality Objectives for Enumeration of Nematodes by the Enumeration Laboratory and Within Fields (October 1991)

| | Precision objectives | | | | |
|---|---|---|---|---|---|
| | Reporting | Laboratory | | Field | |
| Parameter | units | SD | %CV | SD | %CV |
| PLPAR[a] | no./kg soil | 565.7 | 82.1 | 953.5 | 130.8 |
| BACT[b] | no./kg soil | 670.2 | 75.4 | 477.9 | 69.2 |
| FUNG[c] | no./kg soil | 120.9 | 85.6 | 134.6 | 101.2 |
| OMNI[d] | no./kg soil | 28.29 | 139.7 | 33.7 | 185.2 |
| PRED[•] | no./kg soil | 59.33 | 81.6 | 64.7 | 101.4 |
| PLPAR | ln (no./kg soil)[f] | 1.001 | 16.3 | 1.50 | 25.6 |
| BACT | ln (no./kg soil) | 0.702 | 10.7 | 0.723 | 11.5 |
| FUNG | ln (no./kg soil) | 1.860 | 44.8 | 1.546 | 36.5 |
| OMNI | ln (no./kg soil) | 1.849 | 103.5 | 1.804 | 117.3 |
| PRED | ln (no./kg soil) | 1.623 | 44.7 | 1.660 | 48.7 |
| WT_VOL | g/cc | | | | |

[a] Plant-parasitic nematodes
[b] Bacterivorous nematodes
[c] Fungivorous nematodes
[d] Omnivorous nematodes
[•] Predaceous nematodes
[f] Statistical analyses are run on ln (x+1); x = nematode population

NOTE: For the field samples, the DQO is 2X that of analytical samples.

$$\% \text{ CV} = \frac{\text{standard deviation}}{\text{mean}} \times 100$$

**Table 6.1-3.** Metadata for Biological Analysis of Soils in the 1992 North Carolina Pilot

| Variable | Type | Unit[a] | Anal. Method | Lab | Comments |
|---|---|---|---|---|---|
| PLPAR[b] | Integer | no./kg | elutr/sucrs cent | BARKER | |
| BACT[c] | Integer | no./kg | elutr/sucrs cent | BARKER | |
| FUNG[d] | Integer | no./kg | elutr/sucrs cent | BARKER | |
| OMNI[•] | Integer | no./kg | elutr/sucrs cent | BARKER | |
| PRED[f] | Integer | no./kg | elutr/sucrs cent | BARKER | |
| WT_VOL | Integer | g/cc | dry wt. | BARKER | |

[a] All values expressed on an oven-dry soil weight basis.
[b] Plant-parasitic nematodes
[c] Bacterivorous nematodes
[d] Fungivorous nematodes
[•] Omnivorous nematodes
[f] Predaceous nematodes

to measure relative ecological health or stability of the soil. Indices that will be compared include:

- Bacterivores + fungivores (as proportions of total)
- Omnivores + predators (presence-absence categories)
- Omnivores + predators / omnivores + predators + plant parasites (numbers or proportions give the same value); index ranges from 0-1 (ecosystem stability potential/production decrease)
- Omnivores alone
- Dorylaimidae (family of omnivores)
- Predators alone
- Shannon index of diversity (Ludwig and Reynolds 1988)
- Simpson index of diversity (Platt et al. 1984; Ludwig and Reynolds 1988).

The Simpson index has the advantage that, unlike the Shannon index, it does not give disproportionate weight to rare species (Ludwig and Reynolds 1988).

The variance structure will be characterized into laboratory measurement error and within field variation using cumulative density functions (cdf) and box-plots. The cdfs are useful when the cumulative extent of some resource is less than, or equal to, a specified percentile of the data. Box-plots can also be used to display the distribution of the data. They are especially useful in allowing comparisons of several distributions across time and space (Section 3.4.1). Variograms will be used to inspect the covariance structure in the spatially distributed data (Section 3.4.2).

**Interpretation of indices.** Agricultural fields are characterized by an abundance of bacterivorous and plant-parasitic nematodes and a low frequency of omnivores and predators (Wasilewska 1979). High numbers of plant-parasitic nematodes are detrimental tc crop growth and yield. Applications of nematicides initially decrease populations of plant-parasitic nematodes, although populations may increase dramatically later. An abundance of bacterivores, considered together with fungivores, is considered "healthy" (Freckman 1988). High numbers of bacterivores and fungivores infer rapid decomposition rates (especially when *Rhabditis* spp. are abundant), and

may be associated with low organic matter and with either low or high populations of bacteria or fungi. Microbial populations may be decreased by nematode feeding or increased by the feeding activity and feces of nematodes (Wasilewska 1979). Bacterivores are highly resistant to chlorine, fungicides, nematicides (Wasilewska 1979) and herbicides (Dmowska and Kozlowska 1983), and they increase in abundance with cultivation (Wasilewska 1979).

High numbers of bacterivores are generally associated with low numbers of omnivores (< 5% total nematodes) and predators (< 2% of total nematodes) under conditions favoring growth of microflora (i.e. high soil humus content, high organic and mineral fertilization) (Wasilewska 1979). Together, omnivores and predators may serve as a soil bioindicator (Gorny 1976) because they are sensitive to anthropogenic disturbances, including cultivation (Wasilewska 1979). Omnivores and predators have longer life cycles than bacterivores or fungivores and are found in higher percentages in soils with perennial crops than in soils with annual crops (Wasilewska 1979, Bostrom and Sohlenius 1986). Omnivores do not depend on one kind of food; therefore, they represent more stable conditions and more diverse biocenoses. Theoretically, small increases in heterotroph (omnivore) biomass help re-establish system equilibrium and counteract perturbation (O'Neill 1976). The presence of predators lengthens food-chains resulting in greater stability of the soil ecosystem, and their numbers increase when conditions are stable (Wasilewska 1979).

### *6.1.8. Further Research and Eventual Applications*

Investigation of laboratories to enumerate nematode communities by trophic group will continue. Presently, only two investigators in the United States, are known to be qualified to enumerate nematodes by trophic group and in the use of the specified extraction method used [i.e. Kenneth Barker (North Carolina State University) and Diana Freckman (University of California at Riverside)]. Extraction by elutriation and Baermann funnels was compared for a subset of the samples collected during a survey field study conducted in December 1991.

A field study to compare sampling designs, within-field variability, and within-laboratory variability of nematode communities was conducted in October 1991. The results from this study provided the data quality objectives for the pilot study (Table 6.1-2).

The indices developed to describe nematode community structure will be compared for the two surveys conducted across North Carolina in December 1990 and 1991. Using a probability sampling frame, three annual crops (corn, soybeans and wheat) were sampled in 1990. In 1991, nematode communities were compared in an annual crop (soybeans), a short-term perennial ($\geq$ 3-yr alfalfa) and a long-term perennial (pasture for $\geq$ 10 yr). A variety of growth forms were chosen to provide a broad range of index values. In 1991, nematode community patterns were also compared to microbial biomass in soil; total and active bacteria and total and active fungi were enumerated by Elaine Ingham at Oregon State University (Corvallis, OR). Microbial biomass data are being evaluated in reference to nematode populations to evaluate the nematode community indicator's ability to reflect the health of the decomposer foodweb in soil.

Plant-parasitic nematodes were enumerated to genus in both the 1990 and 1991 survey studies. A diversity index such as Shannon or Simpson (Ludwig and Reynolds 1988) will also be applied to that data to determine if, within a single trophic group, it might prove to be an appropriate indicator.

## 6.2. Landscape Structure

### *6.2.1. Introduction*

The rationale for analyzing landscape structure as part of a monitoring program for agroecosystems is described in *Agroecosystem Monitoring and Research Strategy* (Heck et al. 1991), and briefly in Section 5.4 *(Land Use and Cover)* of this document. In short, the spatial structure of the landscape affects the flow of energy and materials, and the movement of organisms, among its components.

The indicators detailed in the *Land Use and Cover* Section provide information about the amount and proportion of various land use and cover classes. These analyses may describe landscapes A, B and C as 65% agriculture and 35% forest. However, in landscape A forested lands may be in three large parcels; in landscape B the forested land may be one large parcel; in landscape C it may be in dozens of small, disjoint woodlots. The ecology of these three landscapes is likely to be quite different. Indicators developed for landscape structure are intended to provide quantitative measures of these and other ecologically relevant differences in the spatial structure of landscapes. Since these indicators will *describe* the spatial structure of the landscape, the terminology *landscape descriptors* has been adopted.

### *6.2.2. Research Objectives*

Many landscape descriptors with ecological relevance have been proposed in the literature (*e.g.*, Turner 1989; Turner and Gardner 1991). However, most work has been theoretical with no attempt to synthesize these measures into the framework of a national monitoring program. The overall objective of the Landscape Structure Research Project is to ***develop a multi-scale, quantitative, and ecologically relevant description of agricultural landscape structure*** using an appropriate combination of landscape descriptors.

Initial research on landscape descriptors will be conducted as part of the 1992 Pilot Project of the Agroecosystem Program. The research will focus on the North Carolina portion of the Albemarle-Pamlico watershed, which covers a large part of the most northern and northeastern portions of North Carolina, as well as part of southern Virginia. This region has been chosen because 1) the 1992 Pilot is being conducted in North Carolina, 2) a Thematic Mapper (TM) based land use and cover GIS database exists for the watershed, and 3) GIS land use and cover datasets are not available for any other large region of North Carolina. Limited resources and the agroecosystem mission of the ARG will further restrict analysis to land in the agricultural strata of the NASS Area Frame.

Specific objectives for the Landscape Structure Research Project are highlighted.

- Select and calculate appropriate landscape descriptors, using TM-based data, for each of the following NASS land use strata within the North Carolina portion of the Albemarle-Pamlico watershed: <15% agriculture, 15-50% agriculture and >50% agriculture.

- Within these three agriculture strata, obtain aerial photography for the NASS PSUs within the Albermarle-Pamlico watershed; the EMAP-Landscape Characterization Group (LCG) (or another contractor) will digitize the scenes according to Level 1 of the Albemarle-Pamlico classification system (Table 5.4-2).
  - With the LCG, determine the best type and source of imagery.
  - Select and calculate appropriate landscape descriptors for these scenes.
  - Analyze variance structure and attempt to determine an optimum number of PSUs to be analyzed.

- Develop and carry out a program (jointly with the LCG) to study techniques for analyzing aerial photography *without* digitizing the entire scene. It is anticipated that such an approach would be less costly than digitizing the entire scene, and ultimately would allow a larger sample to be analyzed. The techniques will be judged on their

ability to 1) accurately reflect the land use characteristics of the scene and 2) accurately reflect the structural attributes of the landscape.

### *6.2.3. Data Acquisition*

This research will utilize the NASS Area Frame coverages and TM data acquired for the analyses described in Section 5.4 of this document. Steps to obtain these data are detailed in that Section.

In addition, the acquisition and digitization of aerial photography will be required (Table 6.2-1). Two sources of photography are currently under consideration.

**Table 6.2-1.** Steps to Acquire Digitized Aerial Photography.

| *Step* | *Target Completion* | *Actual Completion* |
|---|---|---|
| 1) ARG identifies areas (PSUs) for which photos are required. | 6/1/92 | |
| 2) NASS, EMAP-LC, or another contractor obtains appropriate imagery. | 9/1/92 | |
| 3) EMAP-LC (or another contractor) classifies and digitizes at EMAP-LC Level 1. ARC coverages will be produced. | 12/30/92 | |
| 4) ARC coverages shipped to ARG. | 1/30/93 | |

***National Aerial Photography Program (NAPP)***

The 1:40,000 scale black-and-white stereo imagery is available from NAPP for North Carolina for the years 1989 and 1981. The LCG has established procedures for obtaining and digitizing these photographs.

*USDA Agricultural Stabilization and Conservation Service (ASCS) Slides*

The ASCS annually obtains almost complete coverage of North Carolina between May and August. Only large forested areas, such as the Great Smoky Mountains National Park, are excluded. The imagery available is low-altitude (approximately 5200 feet), true-color, 35mm slides. Each slide covers an area of 640-1000 acres, depending upon exact flight altitude. Because ASCS is required to retain these photographs, an historical record is available for North Carolina since 1984. The LCG currently has neither a mechanism for obtaining these images nor the facilities for analyzing them. The ARG personnel have contacted the North Carolina office of the ASCS and have an agreement in principle to obtain copies of these slides. Details could be worked out if this imagery is to be utilized.

### *6.2.4. Essential Complementary Data*

*NASS County Road Maps*

In order to identify the photography required, county road maps showing the location of the sample PSUs will be required. These will be supplied by the North Carolina NASS office.

*Land Cover Classification System*

A classification system is required for the interpretation of aerial photography. Ideally, data from different scales (*e.g.* satellite and aerial photography) should be interpreted according to the same hierarchical classification system. Broad-scale data may be classified using the upper levels of the hierarchy (*ie.* Level 1); fine scale data may be classified in more detail using lower levels of the hierarchy (*ie.* Level 2).

The proposed classification system for the LCG is summarized in Table 6.2-2. The classification system used for the Albemarle-Pamlico study is summarized in Table 5.4-2 (Section

5.4). Differences between them are minor at classification Level 1, most notably the combination of the agriculture and grassland classes in the Albemarle-Pamlico system. This is a reasonable combination of classes for the classification of TM-based data.

For the 1992 Pilot, Level 1 of the LCG classification system will be used for interpreting aerial photographs. Using this system allows a distinction to be made between agriculture and grassland in the PSUs. Separation of agricultural fields from grassland is desirable for comparison with analyses based on data from the June Enumerative Survey collected within the PSU. The two classes may be combined for analyses requiring consistency with TM-based data.

**Table 6.2-2.** Proposed LCG Classification System.

| *Level 1* | *Level 2* |
|---|---|
| Urban / Built-up Lands | High Intensity (Urban Center)<br>Low Intensity (Suburban) |
| Agriculture | Cropland<br>Orchard /Vineyard |
| Grassland | Permanent<br>Man-controlled<br>Pasture |
| Forest | Evergreen<br>Deciduous<br>Mixed |
| Shrubland | Evergreen<br>Deciduous<br>Mixed |
| Water | Marine<br>Estuarine<br>Fresh |
| Wetland | Estuarine emergent<br>Estuarine woody<br>Palustrine emergent<br>Palustrine woody<br>Unconsolidated shore |
| Barren Lands | Permanent<br>Disturbed / Transitional |
| Snow / Ice / Glacier | Glacier<br>Snow / Ice |
| Other | Indeterminable |

### *6.2.5. Logistics and Quality Assurance*

No field sampling is required.

Logistics and QA for the NASS Area Frame and Albemarle-Pamlico data are detailed in Section 5.4.

The LCG has well-established procedures for obtaining, classifying, and digitizing aerial photography from NAPP. If another contractor is chosen they will be required to follow the LCG's QA procedures. If the ASCS photography is required, appropriate logistics and QA procedures will be developed.

### *6.2.6. Metadata Requirements*

Metadata requirements for GIS coverages are described in Section 5.4 of this document.

### *6.2.7. Data Analysis and Integration*

#### *Proposed Landscape Descriptors*

A suite of landscape descriptors is proposed for monitoring agricultural landscapes. These measures, drawn from the literature, describe various aspects of landscape structure which are likely to affect ecological processes. Table 6.2-3 summarizes the landscape descriptors currently under consideration. Formulae and algorithms for calculating these descriptors are described in Appendix A8.3 of the Agroecosystem Monitoring and Research Strategy (Heck et al. 1991).

#### *Thematic Mapper Data*

Figure 6.2-1 summarizes the analysis of TM data. Land areas within the North Carolina portion of the Albemarle-Pamlico watershed will be stratified using the digitized NASS area frame, and the suite of landscape descriptors calculated for each stratum. This analysis will provide broad-scale structural information for each stratum. Preliminary analysis of the Albemarle-Pamlico dataset indicates that stratification at the landscape level will be critical to the interpretation of these data. For example, as a result of fairly heavy tree cover in suburban

**Table 6.2-3.** Landscape Descriptors Currently Under Consideration for use in the Agroecosystem Program.

| *Measure* | *Describes* | *Affects (examples)* |
|---|---|---|
| Fractal analyses | Broad-scale pattern; spatial complexity | Ability of organisms to utilize habitat patches |
| Nearest neighbor analysis | Fragmentation; clumpiness; "connectedness" | Movement of organisms; spread of disturbances |
| Contagion index | Fragmentation; clumpiness | Movement of organisms; spread of disturbances |
| Dissection index | Patch edge-to-area relationship | Types of organisms which may utilize patches |
| Amount of edge of land cover A adjacent to land cover B (%) | Frequency with which Land cover A is directly adjacent to land cover B | Border movement processes (such as flow of sediment into surface waters) |

Raleigh, the area is classified largely as forest. Although accurate from the perspective of a satellite, the ecological characteristics of a tree covered area are very different from those of, for example, the Great Smoky Mountains National Park. Including both of these tree-covered areas in a calculation of the total area of forest resources in North Carolina would be very misleading.

Landscape level stratification, such as the NASS Area Frame, draws a clear distinction between these areas, and calculation of tree-covered areas within each stratum is much more meaningful.

Exactly how each descriptor will be calculated using the available data is one of the unknowns to be determined by this study. Most of the examples in the literature focus on calculating the values for simple geometric shapes (squares are very popular). The methods may not be directly applicable to the irregular polygons of the NASS area frame. Further, many of the measures are sensitive to perimeter length. The artificial edge created by using the NASS stratum boundaries as an overlay must be taken into account.

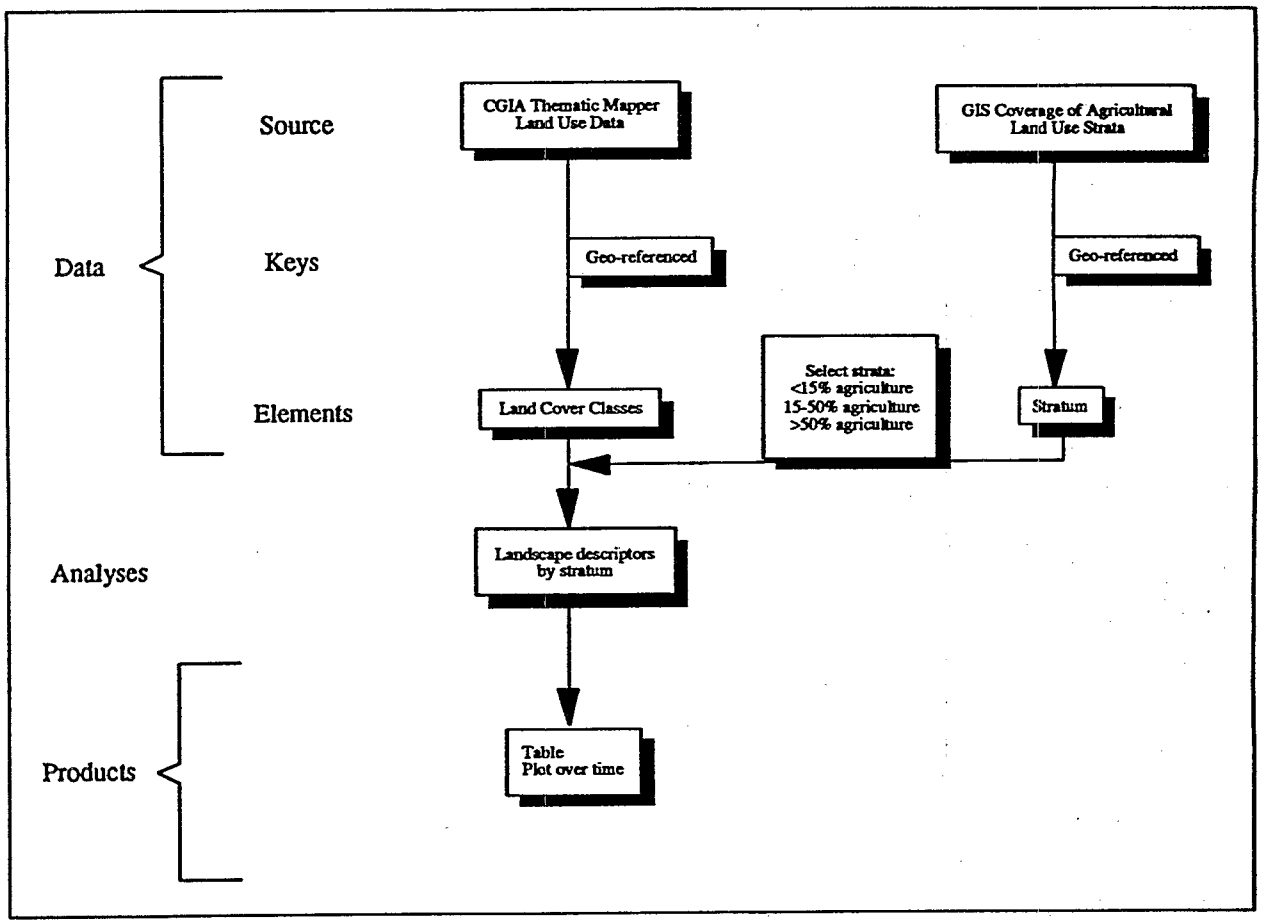



**Figure 6.2-1.** Analysis of Thematic Mapper Data for Landscape Structure.

### *Aerial Photo-Interpretation and Analysis*

Figure 6.2-2 summarizes the analysis of digitized aerial photography. Because extensive interpretation of aerial photographs is too expensive, a sampling approach will be developed for land within the North Carolina portion of the Albemarle-Pamlico watershed. For the Pilot, the PSUs chosen for the Pilot (in the three agricultural strata) will serve as the sample. This will allow landscape measures of the PSUs to be correlated with other indicator measurements obtained during the Pilot (see discussion of overall integration below). For each PSU, the suite of landscape descriptors described above will be calculated. This will provide a statistical measure of fine-scale structure for each stratum. The use of other landscape descriptors (*e.g.* hedgerow length and spacing, number of hedgerow connections) may be explored as resources permit.

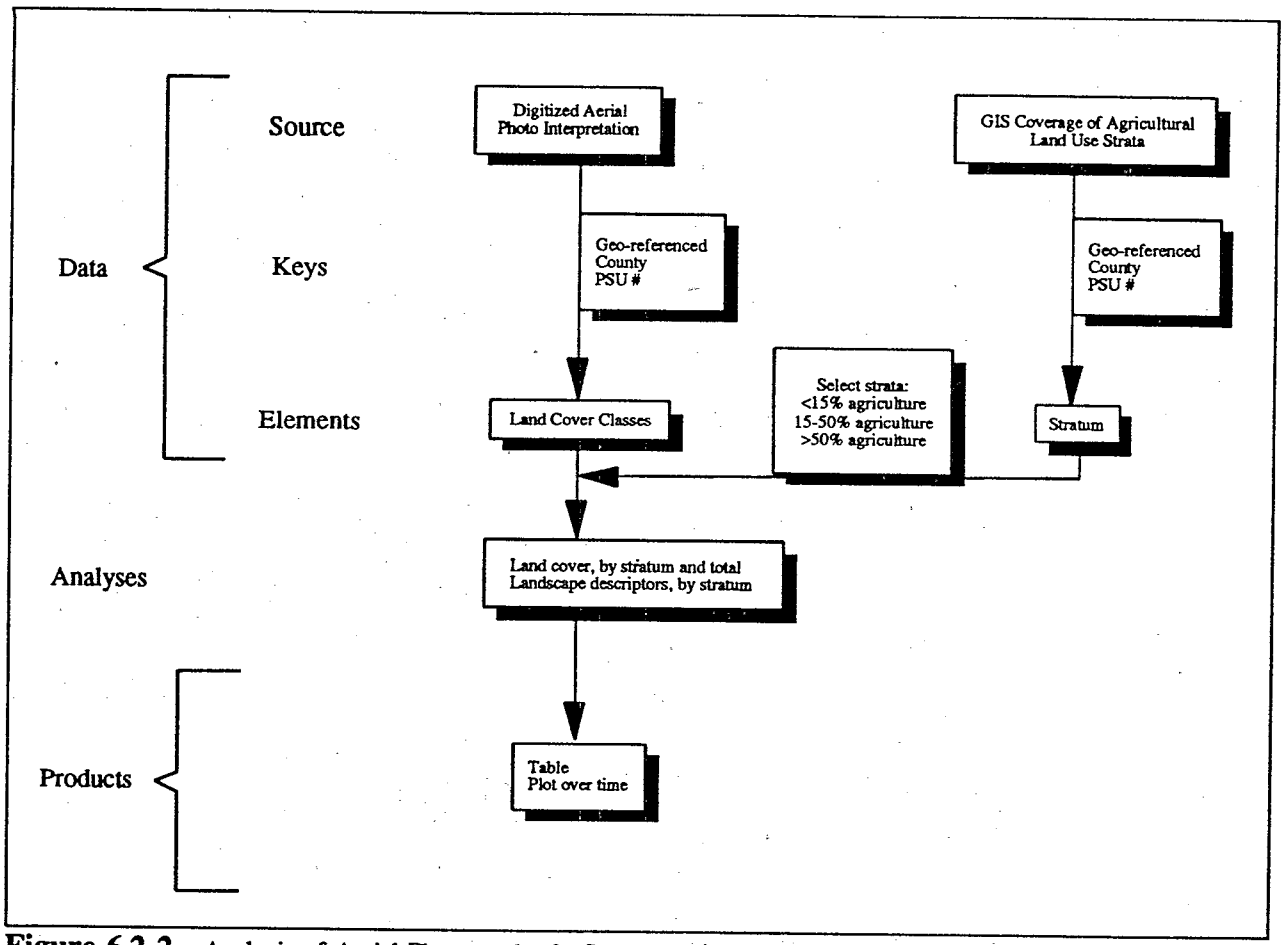



**Figure 6.2-2.** Analysis of Aerial Photography for Landscape Descriptors.

### *Sampling Analysis of Aerial Photographs*

Because aerial photo-interpretation is costly, a study will be conducted in cooperation with the LCG to test various *within-photograph* sampling techniques for analyzing aerial photography. These techniques include 1) applying a grid to the photograph and classifying only the cover under each grid point and 2) classifying several transects across the imagery. These analyses will be carried out using data from the Agroecosystem Pilot as well as data from the LCG Ten Hexagon 1990 Pilot Study. These studies may also be carried out on simulated landscapes. Figure 6.2-3 summarizes an approach to this analysis.

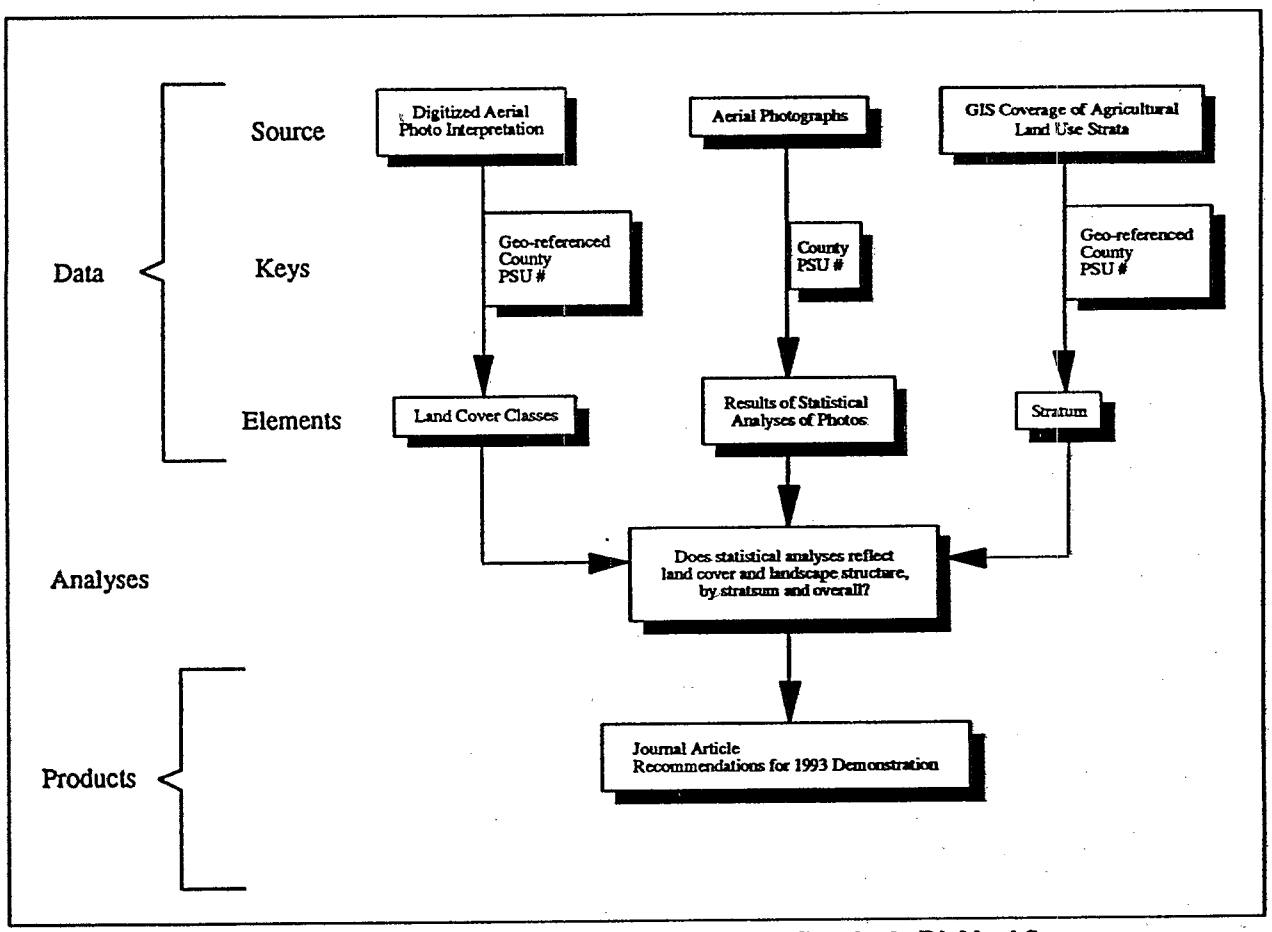



**Figure 6.2-3.** Comparison of Statistical Analysis of Aerial Photos to Completely Digitized Scenes.

### *6.2.8. Further Research and Eventual Applications*

#### *Determination of Error Structure*

"Although the use of remote sensing data for spatial databases is increasing rapidly, our understanding of associated data processing errors, especially for integrating multiple data sets, lags far behind" (Lunetta et al. 1991). A typical procedure of developing a GIS database from remotely-sensed data includes several phases: data acquisition, data processing, data analysis, data conversion, error assessment and final product presentation. Error may be introduced in all phases, and propagated and transformed from one phase to the next. Another level of sampling error is introduced when selecting a sample of PSUs for interpretation. These individual errors

must be quantified, and the way in which they propagate and combine understood, in order to place confidence intervals around landscape descriptors based on GIS data.

This issue of error detection and classification looms large in the future development of EMAP, because many of the proposed products are to be developed using GIS overlay techniques. The Landscape Characterization Group, the GIS team and the Integration and Analysis Group are discussing this issue. The ARG will continue to work closely with these groups, with our ARG statisticians, and with the Statistics and Design Team of EMAP to address this issue.

***Integration Across Scales***

Combining information obtained from TM data with information derived from aerial photography will provide the desired multi-scale perspective. This is an area of current research from which EMAP efforts stand to benefit. The ability to make predictions at one scale using data collected at another scale is desirable but difficult. One approach, which will likely be more profitable, is to develop procedures for using relatively inexpensive satellite data to guide the allocation of resources for the solution of more expensive procedures such as aerial photo-interpretation. Using NASS stratification to select these areas may be a viable approach.

***Overall Integration***

Other indicator data will be collected from fields and non-cropped areas within the PSUs subject to landscape structure analysis. During the 1992 Pilot Project, the focus will be on indicators of crop productivity, soil quality, and nematode populations. Exploratory analysis of the relationships between the values of the indicators and the various landscape descriptors may be carried out as shown in Figure 6.2-4. More detailed research will likely be required to confirm any hypotheses developed from these analyses.

*Landscape Pattern Types*

The LCG is developing a *Landscape Pattern Type* (LPT) classification which could be used to stratify land areas based on certain landscape structural attributes. A comparison of landscape descriptors calculated using the LPT stratification to results from the NASS stratification would be instructive and should be attempted.

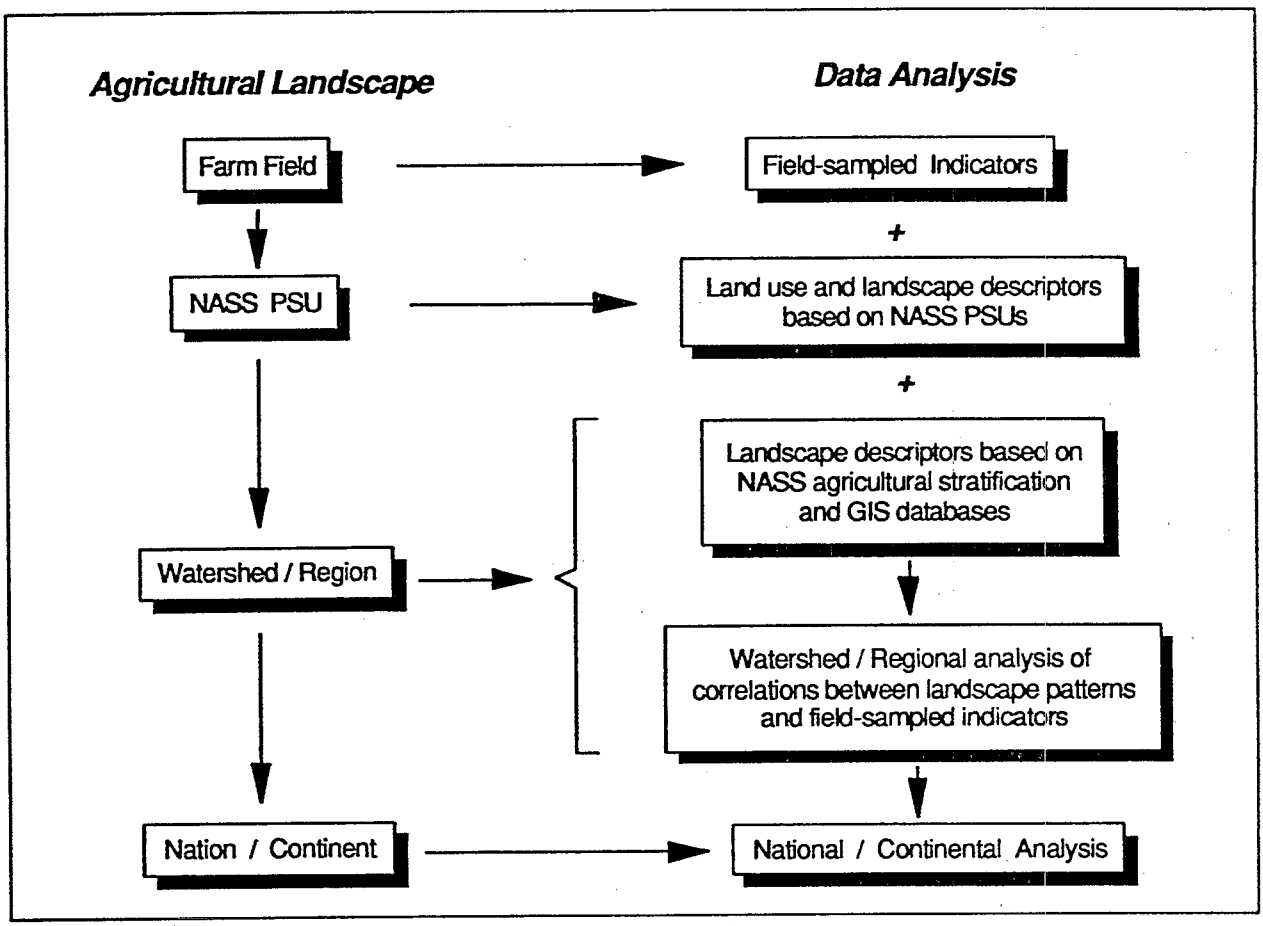



**Figure 6.2-4.** Framework for Exploratory Analyses and Integration.

## 6.3. Water Quality - Groundwater Monitoring, Wells and Modeling

### *6.3.1. Introduction*

Monitoring conducted using existing on-farm wells may be subject to built-in bias and may be of questionable sample quality due to a number of factors (e.g., well construction and materials, location, and type of use). One way to address this question is to compare data derived from existing wells with similar data obtained using "research wells" drilled and sampled under controlled conditions by EPA cooperators from the Environmental Research Laboratory in Athens, Georgia (Athens-ERL staff).

Supplementary research comparing sampling results from existing wells to those from research wells will be conducted at the same time as the Agroecosystem Pilot Project for groundwater model testing. Funding will be through the Groundwater Matrix Management Program at Athens-ERL. This work is expected to complement the Agroecosystem activities and may have an impact on the manner in which future monitoring is implemented.

Mathematical models have become useful tools for predicting movement of chemicals from agricultural sites to surrounding environmental media. For EMAP, models may be useful for estimating export loads to other ecosystems, so that monitoring requirements can be kept to a minimum. A model testing and applications question, therefore, is whether existing groundwater agricultural chemical threat models can be used reliably on large spatial scales as an alternative approach to detailed monitoring for the non-point source loading indicators of the Agroecosystem Program. The DBAPE system (Imhoff et al. 1990) and RUSTIC model (Dean et al. 1989) will be used for this planned research effort.

Two objectives have been identified for this well comparison study.

- Assess the advantages and disadvantages of the use of existing on-farm wells versus "research wells" for monitoring organic pesticides and nitrates in groundwater

- Conduct preliminary field testing of an agricultural chemical groundwater model such as DBAPE/RUSTIC on both a statewide scale (North Carolina) and a county or EMAP hexagon level

### *6.3.2. Sampling Design and Collection by NASS and EPA, Athens-ERL*

This project is research-directed and covers a smaller area of the state than the primary study (Section 5.3). Water samples will be collected and analyzed at the Athens-ERL. This study will compare the relative value of using research wells as opposed to existing wells for detecting contaminants in groundwater. This emphasis will help determine whether existing wells can be used to provide unbiased samples of groundwater quality. Results will also be used to test an appropriate model for its predictive capability.

An area in the coastal region of North Carolina will be identified for use in this more intensive groundwater sampling project. The size of the area will be several square miles and will correspond to some geographic unit compatible with a relatively uniform modelling scenario, possibly to an EMAP hexagon, or to a NASS segment or PSU. A moderate number of research monitoring wells will be installed randomly throughout the area for the purpose of obtaining reliable groundwater samples. A similar or larger number of existing wells will be identified within the same area for the purpose of obtaining groundwater samples. The data derived from these samples will be used for comparison of the two types of wells. Standard statistical methods will be applied. It is anticipated that samples will be obtained from each well on three or four occasions throughout the year.

Detailed groundwater model predictions will be developed for the sampling area. Model performance testing will be conducted using the methodology of Parrish and Smith (1990) on both the existing-well and research-well data.

### *6.3.3. Essential Complementary Data*

Additional site data for parameterizing models will be required. These data will be obtained from sources such as SCS. Data will include, but not be limited to, the following: soil series, specific horizon depths, texture, areal distribution, depth to water table, horizon thicknesses, hydraulic conductivity (by horizon), soil water retention, chemical degradation rates, retardation (bulk density, field capacity, partition coefficient), meteorology data and chemical application rate. Much of this will be derived from existing databases using DBAPE (Imhoff et al. 1990).

### *6.3.4. Logistics*

All samples are to be collected by the Athens-ERL staff, transported to the analytical laboratory, stored on ice and kept frozen until analyses are complete. Standard protocols will be followed for sampling wells.

Location of the intensive research study area in the North Carolina coastal plain will be coordinated with local representatives to identify sites suitable for research-well installations and existing-well sampling.

### *6.3.5. Quality Assurance*

Sample Collection

All water samples must be properly collected (i.e., according to protocol) in one-quart amber glass bottles (Athens-ERL will supply sampling containers). Fortified samples will be held under identical storage conditions to assess storage stability. Ten percent of field samples will be analyzed in duplicate. Outliers will be analyzed in triplicate, if possible.

Prior to the collection of field samples, duplicate spiked samples will be run at several concentrations to determine method accuracy and precision and to establish lower limits of

detection. During the analysis period, fortified recoveries will be analyzed as dictated by the situation, but not less often than one set per month. Spiking levels and range will be determined at that time.

One reagent blank will be run each time samples are extracted (sample set). Standard instrument calibration curves will be prepared at least once each instrument operating day. Individual laboratory log books and instrument log books will be kept current and reviewed by the project officer on a regular basis. Analytical standards will be obtained from the EPA repository at Research Triangle Park, N.C. or check-analyzed against an EPA standard if obtained from another source.

Data Quality Objectives (DQO) will be established prior to the generation of sample data. Approved EPA methodology will be utilized whenever possible and standard operating procedures (SOP) referenced or written as needed. Quality-control activities are a key component for assuring high-quality data. Samples will be analyzed in random order, to minimize systematic bias attributable to laboratory procedural techniques and to ensure objectivity in measurements. Such randomization of samples helps ensure that observed trends are actually due to field responses.

Laboratory Analyses

Analytical support for this research will be at EPA's Environmental Research Laboratory, Athens, Georgia. Analysis of pesticides will require analytical sensitivities in the low parts-per-billion range in extractions from both water and sediment. The analysis requires production-line efficiency for large numbers of samples with multiple extractions. Depending on the sample type and the test compounds, samples will be extracted using solid phase, liquid-liquid, ultrasonic, or Soxhlet extraction techniques. Also, depending on the test compounds, the analyses of the extracted residue will be conducted by gas chromatography using electron capture (ECD), flame photometric (FPD), nitrogen-phosphorus (NPD), or Hall electrolytic conductivity (Hall ECD)

detection systems or high pressure liquid chromatography utilizing post column reaction (PCRS) and ultraviolet (UV) detection systems.

Depending upon available resources, residue analyses at Athens-ERL may include atrazine, carbofuran, aldicarb, other selected pesticides, metabolites and nitrate.

### *6.3.6. Metadata Requirements*

Metadata will include methods of analysis, reporting units, data formats and pertinent comments by samplers or laboratory personnel.

### *6.3.7. Data Analysis and Integration*

Standard techniques will be used for statistical data analysis and modelling activities.

## 6.4. Biological Ozone-Indicator System

### *6.4.1. Introduction*

Tropospheric ozone ($O_3$) causes more damage to plants than all other air pollutants combined. Thus, there is increasing interest in developing ways to monitor its effects on ecosystem health. A useful tool in such an effort would be a plant system that produces measurable responses to ambient levels of $O_3$ and can be calibrated to estimate $O_3$-induced losses to important plant species; such a system might be able to estimate the biological responsive $O_3$ concentration. Optimally, such a system would account for potential effects of climatic variables on plant growth and vigor per-se and on the magnitude of its response to $O_3$. A system that can predict changes on a short term basis would be preferred to one that has a single seasonal endpoint.

A plant system that utilizes the relative response to $O_3$ of two clones of white clover *Trifolium repens* L. has undergone preliminary field testing and has the potential to meet the criteria given above. The clover system can separate the effects of climate per-se from $O_3$ response because it utilizes the differences in response between an $O_3$-sensitive clone (NC-S) and an $O_3$-resistant clone (NC-R). Results from three years of field tests at Raleigh, North Carolina indicate that both clones show similar response to climatic conditions and that clonal differences in growth, foliar injury and foliar chlorophyll content were due to differences in sensitivity to $O_3$.

The goal of this project is to use the differences in $O_3$ sensitivity of NC-S and NC-R to estimate biologically active $O_3$ doses and ultimately, to estimate the impact of $O_3$ on agricultural ecosystems. Clonal differences in foliar injury symptoms (chlorosis and necrosis), foliar chlorophyll content, and biomass production will be used as estimators in 1992.

### *6.4.2. Background*

The NC-S and NC-R clones were survivors of a two-year field study (Heagle et al. 1989, Rebbeck et al. 1988) in which a mixture of white clover (Regal) and tall fescue, *Fesctuca arundinacea* Schreb. (Kentucky 31), was exposed to six levels of $O_3$ in open-top field chambers from April to October over two seasons. Ozone caused significant decreases in white clover growth with a simultaneous increase in fescue growth, probably due to decreased competition from clover. After two seasons of exposure, there was a decline in the number of live clover plants in the high $O_3$ treatments, while clover was still thriving in the low $O_3$ treatment. Cuttings from clover plants that survived the two-year field experiment were propagated vegetatively. One clone (NC-R) that survived exposure to the high $O_3$ treatment (seasonal 12 hour per day mean of 89 ppb) was subsequently shown to be highly resistant to $O_3$. The other clone (NC-S) was selected from a charcoal-filtered-air plot (seasonal mean of 26 ppb) and was shown to be highly sensitive to $O_3$. Methods used in the selection and development of these clones have been published (Heagle et al. 1991).

Three seasons of field testing (1989-1991) have shown that foliar injury, foliar chlorophyll content and seasonal biomass production of both clones are directly related to the $O_3$ concentration and that NC-S is always the more sensitive of the two. Ambient levels of $O_3$ in Raleigh routinely injure leaves and decrease growth of NC-S but not NC-R. At higher $O_3$ levels, both clones show response to $O_3$ but NC-S is always much more sensitive.

### *6.4.3. General Approach*

Virus-free plants (Heagle et al. 1991) of the two white clover clones will be propagated vegetatively in a charcoal-filtered-air environment. Sixteen field sites will be selected to provide a range of meteorological conditions, to include ozone. The sites chosen will be within reasonable proximity to an $O_3$ and meteorology monitoring station or will have one at the site. Plants will be transported to field sites in early May and transplanted into large pots (30 cm diameter) containing 15 liters of a uniform potting medium. Plants will be watered as needed to prevent

moisture stress and will be fertilized regularly. At 28-day intervals over a 112-day period, leaves will be sampled to estimate foliar injury and to measure chlorophyll. Clover forage will be cut, dried, and weighed. Foliar injury of NC-S and NC-R and the NC-S/NC-R ratios for chlorophyll and forage biomass will be used to estimate the $O_3$ concentrations for individual 28-day periods and for the entire 112 days. Relationships between climate, $O_3$ concentrations, and the relative response of NC-S and NC-R will be defined.

Most of the detailed methods to be used in this pilot project were published with results of a field study performed in 1989 (Heagle et al. 1992); Appendix 8. Changes or additions to the published protocols are provided with the outline of the procedures given here.

### *6.4.4. Cultural Methods*

Virus-free plants of NC-S and NC-R will be maintained in the Southeastern Plant Environment Laboratory at North Carolina State University at Raleigh, NC. Periodic enzyme-linked immunosorbent assay (ELISA) (Heagle et al. 1991) tests will be performed to insure the virus-free status of the plants. Rooted cuttings from this stock will be used in all field tests. During the second week in March, stem cuttings containing from four to five nodes each were placed in small (10 cm diameter) pots containing Metro-Mix (Metro Mix is a commercial mixture of peat, perlite, and vermiculite with nutrients). Two weeks later, plants were inoculated with *Bradyrhizobium* to promote nodulation and nitrogen fixation; each pot was fertilized with 150 ml of a solution containing 2 g of soluble fertilizer [ 5-11-26 (N-P-K)].

Plants will be moved to the field sites during the second or third week in April and transplanted to 30 cm diameter (15-liter capacity) pots containing a mixture of 2 parts sandy loam top soil, 1 part coarse washed sand, and 1 part Metro Mix. Plants will be watered to prevent moisture stress and will be fertilized at two-week intervals with one liter per pot of the fertilizer solution described above. Insects, will be controlled with applications of Talstar (an artificial pyrethrin) at two-week intervals starting immediately after the first cutting. Water requirements of the plants will vary widely, depending on the amount of foliage present and weather

conditions. For example, daily irrigation will probably be required to prevent wilting during the week before harvests under normal summer conditions in North Carolina, while no irrigation will be needed on the day or two after harvests under most conditions.

The experimental exposure period will begin once the plant canopy covers the soil surface (no soil visible from above) on more than 80 % of the pots at a given site. At this time, plants will be cut at a height of 7 cm (pre-study harvest). We anticipate that the pre-study harvests will occur during mid May.

### *6.4.5. Monitoring Design*

The monitoring design at each site will be two replicates of three pots each per clone. Each replicate will consist of three randomly positioned pots of each clone in a rectangular arrangement. The replicates will be spatially separated from each other. Plants will be sampled on an individual pot basis on four dates at 28-day intervals after the pre-study harvest (after 28, 56, 84, and 112 days). The data from each of the three pots per clone in each replicate will be pooled for statistical analyses. The data will be analyzed for each 28-day harvest and for various combinations of the four 28-day periods.

The sixteen-site monitoring design for the 1992 Pilot will focus on four widely spaced sites in the Eastern half of North Carolina. Four research stations of the NC Agricultural Research Service will be the primary monitoring locations (Raleigh, Rocky Mount, Plymouth and Whiteville). Four locations (on the station or on farms in the near vicinity of the station) will be identified for each research station. Each research station has a meteorological monitoring station. Two ozone monitors will be located at each research station. Preliminary review of ozone data suggests the 12-hr/day mean ozone concentrations averaged over the 28-day growth period will differ at several of the four primary locations. Monthly meteorological data may also differ, but we have not seen data to support this comment.

### *6.4.6. Logistics and Quality Assurance*

The ARG members will be responsible for the operation of this indicator system. The basic handling of plant culture has been covered (Section 6.4.3, 6.4.4 and Appendix 8). A State Extension Specialist has been contacted and is taking the lead to contact county extension personnel to cooperate in the program. The county personnel will identify the farmers most likely to cooperate and will visit the farmers with our ARG representative(s). Once an understanding is reached, each monitoring site will be set up with the requisite number of pots containing each clover clone. Provisions will be made for semi-automatic watering of the pots. The participants (farmers or research station personnel) will be trained in the care and handling of the monitoring station. Each site will be visited by ARG personnel every two weeks. The first visit after the site set-up will be to bring the plants, set them up and review care with the operator. The second visit (2 weeks) will be for site inspection and special care for the plants (fertilizing and preventive pesticide spray). On the third visit (mid-May) the plants will be cut to the 7 cm height and the pre-study harvest will be completed. A revisit of system care will be done and all details completed for the four month (28 days each) monitoring design. Henceforth at 2, 6, 10, and 14 weeks each site will be visited for routine care (fertilizing and pesticide) and a check of plants. At weeks 4, 8, 12 and 16 the routine care and check will be done as well as the collection of all data. Logistics will be developed so that the 4-, 8-, 12- and 16-week visits are each accomplished in a two-day time frame.

Quality assurance (QA) is built into each step of the process. Initial site operator training will be done by a single ARG member. The basic areas of QA include: 1) care of mother plants, culture of cuttings and transplanting; 2) operator training and care of plants in the field; and 3) sampling and analytical procedures.

Details for logistics and QA will be developed as the program develops during the Pilot phase. A detailed protocol will be ready for either the 1993 demonstration or the 1993 pilot.

### *6.4.7. Metadata*

Metadata will include all the details associated with the design and collection of data from the 16 study sites. Additionally, it will include information associated with the ozone and meteorological data. Protocol for handling these data will be developed during the Pilot study.

### *6.4.8. Data Analysis*

Injury Estimates - Injury estimates involve the potential for subjectivity and bias, but this is a rapid procedure that, with practice ("calibration"), can achieve close agreement (within + or - 5%) between different estimators for given leaves. Estimates of foliar injury will be made as the total percentage chlorosis and necrosis (in 5% increments from 0-100%) on each of 5 adjacent trifoliolate leaves per stem on one randomly selected plant of each clone per replicate (2 plants per clone per site). The physiological maturity of leaves measured will be standardized by using the youngest "fully expanded" leaf as the first leaf on each stem. Injury estimates will be made and recorded separately for individual trifoliolates at each stem position.

Chlorophyll Measurements - Leaves used for the injury estimates will be used for the chlorophyll analyses. The five leaves from each of the plants will be placed in approximately 70 ml of ethyl alcohol in a brown glass bottle (150 ml capacity) and placed in the dark. After 3 days, the volume of alcohol for each container will be increased to 100 ml and chlorophylls a and b will be measured spectrophotometrically. Dry weights of each 5-leaf sample will be used to convert the chlorophyll values from micrograms per liter of solution to micrograms per gram of dry leaf sample.

Biomass Measurements - Above-ground biomass (forage) production will be measured by cutting the plants at a height of 7 cm above the soil surface. Stolons growing outside of the 30 cm pot diameter will also be cut. The cut forage (leaves, petioles, and/or flowers and stolons) from each pot will be placed in paper bags, dried in an oven, and weighed.

# 7. Quality Assurance

## 7.1. Introduction

Decision makers, the public, and other users of EMAP data must have a high degree of confidence in the data and statistics generated by the Program. The purpose of quality assurance is to ensure that the data will yield sound and unbiased conclusions related to the principal questions being addressed. Quality assurance (QA) for the Agroecosystem Program is being developed to assure the reliability of measurements. It is recognized that the development of a QA plan is an iterative process. Thus, we expect to learn much in the Pilot that will enhance the QA plans. In the Quality Assurance Project Plan (to be completed before full Program implementation) several key components of QA, including data quality objectives, standard operating procedures, QA project plans, audits, QA annual reports, and work plans will be developed. The general philosophy on QA for the ARG is clearly developed in the Research Strategy document (Heck et al. 1991). QA information will be incorporated into the metadata associated with Pilot data.

## 7.2. NASS Quality Assurance Procedures

Because the Agroecosystem Program is being developed as a cooperative effort between the USDA/ARS, the EPA and USDA/NASS, the ARG will take advantage of QA procedures already employed by NASS. NASS views quality control as the process of eliminating as many survey errors as possible. To limit errors, every survey process must be associated with some type of quality control procedure. The ARG intends to use all of NASS's established quality control procedures in each survey process. The major survey processes in the Agroecosystem Pilot Project amenable to quality control considerations include:

Area sampling frame
- Construction
- Maintenance
- Sampling

Survey specifications
Questionnaire design
Preparation of manuals
- Interviewer's
- Supervising and Editing

Survey software
Training schools
Survey management
Questionnaire handling/processing
Manual data review and coding
Data edit and review
Summarization
Post-survey evaluations
Survey research

The ARG will work with NASS personnel to identify sources/writeups on QA to cover those areas above that will be incorporated into the Agroecosystem Program.

### *7.2.1. Area Frame Development*

General procedures for selection of Pilot segments according to either the rotational panel or hexagon scheme are presented in Section 3.1. Prior to drawing segments, however, the area frame must have been constructed. This activity is handled by NASS, so the QA work rests with them, as will the QA to cover the selection of segments. 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 double-counted or unintentionally omitted, and that strata are correctly identified. QA is also an issue in sampling from the area frame (e.g., in marking off sample segments, Cotter and Nealon 1987). The development of PSUs around EMAP hexagon centroids is a new activity for NASS. The GIS lead within the ARG is verifying these PSUs to assure that they contain the appropriate hexagon centroid.

### *7.2.2. Conversion of NASS Area Frame to ARC/INFO Format*

The current NASS strata, developed in 1978, will be used in the development of a land use indicator (Section 5.4). As a part of this process, the Area Frame is being converted to ARC/INFO format. This process requires special boundary checking and careful tracking of error

sources. The latter is an area of current investigation. Further information about these issues can be found in Table 5.4-1 and in Section 5.4.6.

### *7.2.3. Survey Data: Collection, Processing and Output*

The QA procedures utilized by NASS will be identified and developed in this section. We do not plan to include all the detail here, but we will reference sources and have copies available for review. The ARG will be responsible for data summarization and will develop the QA for these procedures.

Survey data for the ARG will come from two surveys administered by NASS: the June Enumerative Survey (JES) and a special Agroecosystem questionnaire. The JES is NASS's annual effort to collect land use data. NASS will add eight questions to the JES for the ARG 1992 Pilot: three regarding farm ponds, three on wells and two on land use (irrigated acres and idle cropland in government programs). The Agroecosystem 1992 Pilot Study Questionnaire (i.e., "Fall Survey") requests information on yields and management practices; it is reproduced in Appendix 5, as are the eight additional JES questions.

NASS has procedures for both controlling and assessing the quality of the data collected by their surveys. Unless otherwise noted, these procedures will apply to both of the surveys described above. The process starts with the survey specifications. The actual Pilot Questionnaire, along with the questions added to the JES, have been developed in cooperation with the ARG. Close contact between NASS and the ARG is one way in which quality is being assured.

Enumerator training is the next important part of quality control. For the JES, a national workshop will be held in April 1992, with the state "school" to follow in May 1992. The Fall Survey, which will actually start in November, will run concurrently with the sampling of soil and water. NASS and the ARG will cooperate in planning and running the training session for

these activities. NASS enumerators will be taking soil and water samples, as well as interviewing farmers.

Once field interviews begin, the supervisory enumerators are responsible for assuring that data are taken correctly. They 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 needed.

For both surveys, approximately two interviews from each enumerator's workload will be checked by telephone follow-up. Questions from a worksheet will be asked, to verify that the interviewer did contact the farmer, that a particular crop was grown, etc. Such worksheets will be printed in the Supervising and Editing manuals (see below). For the JES, the supervisory enumerator does an on-the-ground check of a couple of random farmers from each enumerators workload, to be sure that field boundaries were drawn correctly. The responsibilities of supervisory enumerators are given in the *NASDA Supervisory Enumerator Handbook* (USDA/NASS, 1990). NASDA is the National Association of State Departments of Agriculture.

Two manuals will be prepared for each survey: an Interviewer's Manual and a Supervising and Editing Manual. These are done annually for the JES (e.g., USDA/NASS 1991a) and will be developed separately for the Agroecosystem Fall Survey. They will be published in May 1992 for the JES and in October 1992 for the Fall Survey. For the latter, the instructions for interviews will be part of an Enumerator's Manual that will also cover soil and water sampling.

Survey data are subject to a three-stage editing process. First, the supervisory enumerator checks the data for reasonableness and sends the questionnaire back to the enumerator if there are problems to be resolved. Once received by NASS, questionnaires are edited by a statistician, who returns unsatisfactory forms to the supervisory enumerator. After these two manual edits, data are entered into the computer, where another detailed edit is performed. The computer verifies that responses are appropriate to questions, runs tests for internal consistency and checks

that data items are within the expected ranges for North Carolina. Problems discovered at this level are brought to the attention of the statistician.

The statistician scores the quality of the enumerator's work on a scale of 1-5 for each interview. These scores are reported back to the supervisory enumerator for both surveys. For the Fall Survey only, enumerators will rank the quality of the interview (scale to be developed). A post-survey analysis is done to calculate response rates, account for costs, and similar items. This is described in Section 8, Logistics.

### *7.2.4. Field Samples*

Several steps in the field sampling process have quality assurance as one of their functions. These include enumerator training, duplicate sampling, sample shipping and sample tracking. Several of these are described below.

#### 7.2.4.1. Soil Sampling

One of the first steps in assuring the quality of soil samples will be the training of enumerators. This will be done cooperatively by NASS and the ARG before the enumerators begin the Fall Survey and sampling. There are no plans to double-check on enumerator performance by re-sampling any fields, although ARG members will accompany enumerators on a few of the sampling trips and will be available to answer questions and troubleshoot problems.

Three sources of variation will be distinguished in soil data: variation among fields, variation within fields, and variation of laboratory analyses. These will be sorted out by sampling second transects in certain fields and by splitting certain of those samples in two (for separate analyses). These procedures are detailed in Section 3.3.3. The current plan is that the extra transect will be sampled in every sixth field, and half of those second-transect samples will be split. Appendix 7 is a detailed table showing the number of regular, repeat, and duplicate (split) samples, as well as "knowns". This and other QA for soil quality measures is addressed in

Sections 5.2.5 and 6.1.5. These sections are primarily concerned with what happens to the sample once it is taken from the field. Proper procedures for mixing, shipping and tracking the samples (Sections 5.2.4 and 5.2.5) will ensure that they arrive quickly and in good condition at the processing and analysis laboratories.

The soil series of each sample field will be determined by comparing the NASS aerial photograph (on which the field has been outlined) with the most recent soil survey photography. To satisfy confidentiality requirements, this will need to be done at the Raleigh NASS office. The SCS may be asked to provide assistance by visiting some fields to verify those soil types.

7.2.4.2. Water Sampling

Selection of farm ponds and wells to be sampled will follow the procedures given in Sections 3.3.4 and 5.3.2. Data quality will depend on adherence to sampling procedures given in Section 5.3.2. These include instructions for the location and depth at which pond samples must be taken. Also specified are the type of container (glass only) and methods for compositing the water samples and then subsampling. Six samples are to be drawn to form each composite sample, from which a sample will be taken for analysis. When sampling from wells, a critical step is to properly purge the system before taking the sample (Section 5.3.2). Prompt chilling and shipping of water samples is also essential. Enumerator training will be important for both quality assurance and for safety. Members of the Athens-ERL will assist in pre-testing of the methods and in training enumerators, although they will not take any of the actual samples from the area frame segments.

One of the issues unique to the pond water quality indicators is the effect of the sampling method on data quality. If a simple and reasonable way of taking samples from the bank of the pond can be devised, it will compared to the standard method of using a boat (Sections 3.3.5 and 5.3.2). There would be a logistical advantage if boats are not needed, but samples taken from the bank may be biased. To answer this and other questions about data precision, some ponds will be sampled with both the "boat" and "bank" methods. From a subset of those ponds, a

second, independent composite sample will be taken using each method (Section 3.3.5), for study of within-pond sample variation.

### 7.3. Soil Quality Measurements

The quality of the sampled soil will be evaluated using both physical/chemical and biological measurements. Our current approach to QA in these areas is found in Sections 5.2.5 and 6.1.5. These include procedures for tracking and archiving samples. Such precautions should help reduce the number of missing data points and also will provide information such as the length of time that each sample spent in transit between the field and the laboratories. There are also procedures for checking laboratory precision and, to a limited degree, accuracy. One in six field samples will be split (to test within-lab variability), and one in 40 soil samples will be a "known". The expected batch size is 40 samples. The source of "knowns" is still to be determined. Such samples will serve as a type of accuracy check on the laboratory analyses. Also, data from the State Soil Survey Database (SSSD) will be used to develop range checks for soil quality measurements from the various soil types. It is not feasible to submit check samples with known nematode numbers (Section 6.1.5).

Quality assurance procedures that are to be followed by the laboratories doing soil analysis or nematode counts will be specified in the contract or interagency agreement, whichever is appropriate. The EMAP Quality Assurance Program Plan requires that a QA Review form (QAR-C, Revision 1, 1981) must accompany all procurement/order requests over $25,000 (U.S. EPA 1991a). Proposed methods for soil analyses are given in Appendix 4. We will work to improve QA documentation during the Pilot Project. One purpose of the Pilot is to identify and improve both the QA and logistics plans.

### 7.4. Water Quality Measurements

QA procedures currently found in Sections 5.3.5 and 6.3.5 will be followed during the Pilot and revised following the Pilot experiences. They include the use of fortified samples, duplicate

analysis of ten percent of samples, and triplicate analysis (if possible) of outliers. Also covered are procedures for reagent blanks, instrument calibration curves, log books, analytical standards, and the random ordering of samples. Data quality objectives are to be determined before the data are produced (Sections 5.3.5 and 6.3.5). The laboratory which will be analyzing the water samples has extensive experience in quality assurance.

### 7.5. GIS Data for Albemarle-Pamlico Regions (Landscape Measures)

QA for GIS data for the Albemarle-Pamlico area will be obtained from Khorram et al. (1991), as mentioned in Section 5.4.3. One possible way of checking the quality of landscape indices will be to test their robustness to shifts in boundaries.

### 7.6. Additional Data

Additional data needing QA includes weather data, conversion factors (such as NPP conversion factors and moisture contents, see Section 5.1.3), and other acquired data. We expect this to be a difficult section to complete because we are dealing with data over which we have no control. QA for aerial photography from NAPP will follow procedures developed by the EMAP-LCG. QA procedures will need development if ASCS photography is used (Section 6.2.5).

### 7.7. Data Quality Objectives

The process of developing data quality objectives (DQOs) for the Pilot indicators is only just beginning. Variances generated from Pilot data will be used, along with assumptions about temporal correlations, to help set achievable DQOs (Section 3.3.7). A few measurement quality objectives have been proposed for the soil physical and chemical properties (Tables 5.2-12 and 5.2-14) and for nematode counts (Tables 6.1-1 and 6.1-2), based on preliminary samples taken in 1990 and 1991. A guidance document for DQOs in EMAP is now in draft form.

# 8. Logistics

## 8.1. Introduction

Implementation of the Agroecosystem Pilot Project has required detailed logistics planning, including coordination and oversight of all support and data collection activities. Although not complete, all activities listed in Table 8-1 have been considered by the ARG. The logistics activities are closely tied to both QA and information management for the Pilot Project. Logistics considerations for each indicator are included in each indicator subsection (Sections 5 and 6 of this document). A schematic of the logistics for the Pilot is given in Figure 8-3 at the end of this section. A Logistics Notebook will be maintained by the ARG with details on logistics for the Pilot.

**Table 8-1.** Logistical issues that have been addressed by the ARG.

| |
|---|
| Staffing |
| Design of Survey Questionnaires |
| Communications |
| Training |
| Safety |
| Sampling Schedule |
| Site Access and Reconnaissance |
| Procurement and Inventory Control |
| Field Operations |
| Laboratory Operations |
| Waste Disposal |
| Information Management |
| Quality Assurance |
| Cost Tracking |
| Review of Logistics |

## 8.2. Logistics and the NASS

A major goal of the Pilot Project is to determine whether the NASS enumerators can collect all field data required for the indicators being tested in the Pilot. The enumerators, operating within the NASS organization, will use procedures selected and developed jointly by the ARG and NASS. From the standpoint of logistics, working with NASS has several benefits. Based on the integrity and reliability of their personnel, NASS has developed a relationship over time with the agricultural community which will greatly facilitate the collection of data. Additionally, NASS has a fully developed infrastructure for the collection of agricultural data, including well-developed logistical procedures and strict quality controls. Use of this infrastructure greatly reduces the resources that would be needed for the ARG to develop similar procedures. The

ARG is using the Pilot to define more completely the interactions between NASS and the ARG and to further develop and refine logistics procedures for the 1993 demonstration/pilot projects. Some NASS procedures are documented in non-published sources such as the Interviewer's Manual. Copies of these documents will be obtained by the ARG and will be available for review at the ARG headquarters in Raleigh, North Carolina.

## 8.3 Specific Logistics Elements

Any EMAP logistics planning needs to consider fifteen elements (Baker and Merritt 1991). These elements are discussed below as they apply to the four Pilot activities: the June Enumerative Survey (JES), the Fall Survey, soil sampling and water sampling. Sampling will take place during the Fall Survey.

### *8.3.1. Overview*

Table 8-2 lists the major activities involved in developing the 1992 Agroecosystem Pilot and identifies the responsible party for each activity. The flow of the major activities planned for the 1992 Pilot is diagrammed in Figure 8-1. This figure shows sampling and survey activities, on- and off-frame activities with general locations, general data flow and responsible parties.

### *8.3.2. Staffing*

The ARG will maintain a scientific and statistical staff for the analysis and synthesis of the information collected. Appendix 1 lists the names and addresses of the Agroecosystem Resource Group members. The ARG consists of a group of eight scientists located in Raleigh, North Carolina and a number of other individuals at locations such as Athens, Georgia; Idaho Falls, Idaho; Corvallis, Oregon; and Las Vegas, Nevada. Pilot activities will be coordinated from Raleigh where the Technical Director, Associate Technical Director and most of the indicator leads are stationed. Raleigh is also where the North Carolina state office of NASS is located. Responsibility for the development of indicators and indices of agroecosystem health will reside

**Table 8-2.** Activities in the 1992 Agroecosystem Pilot Project

| *ACTIVITY* | *RESPONSIBLE PARTY* |
|---|---|
| Statistical design | ARG Statistical Team |
| Selection of segments | ARG Statistical Team |
| Developing indicators | Indicator leads |
| Obtaining ancillary data | ARG IM |
| Testing sampling procedures | NASS/ARG/Athens-ERL |
| Developing survey questionnaires | NASS/ARG |
| Writing manuals: | NASS/ARG |
| - Enumerator's/Interviewer's | |
| - Supervising & Editing | |
| Training enumerators: | NASS/ARG/Athens-ERL |
| - June Enumerative Survey (JES) | |
| - December Survey and sampling | |
| Equipment procurement - Survey | NASS |
| Equipment procurement - Sampling | ARG |
| Conducting the JES | NASS Enumerators |
| Selection of fields, ponds and wells | ARG Statistical Team |
| Clover biomonitor | ARG/Extension Service |
| December Survey | NASS Enumerators |
| Initial summarization of survey data | NASS |
| Survey Administration Analysis (includes cost estimates) | NASS |
| Sampling: | NASS Enumerators |
| - Soil | |
| - Pond water | |
| - Well water | |
| Comparison of existing vs. research wells | Athens-ERL |
| Soil processing | ARG |
| Soil analysis | Contract Laboratory |
| Water analysis | Athens-ERL |
| Compiling of data | ARG IM |
| Indicator calculations and analysis | ARG |
| Sample Statistical Summary and Interpretive Report | ARG |

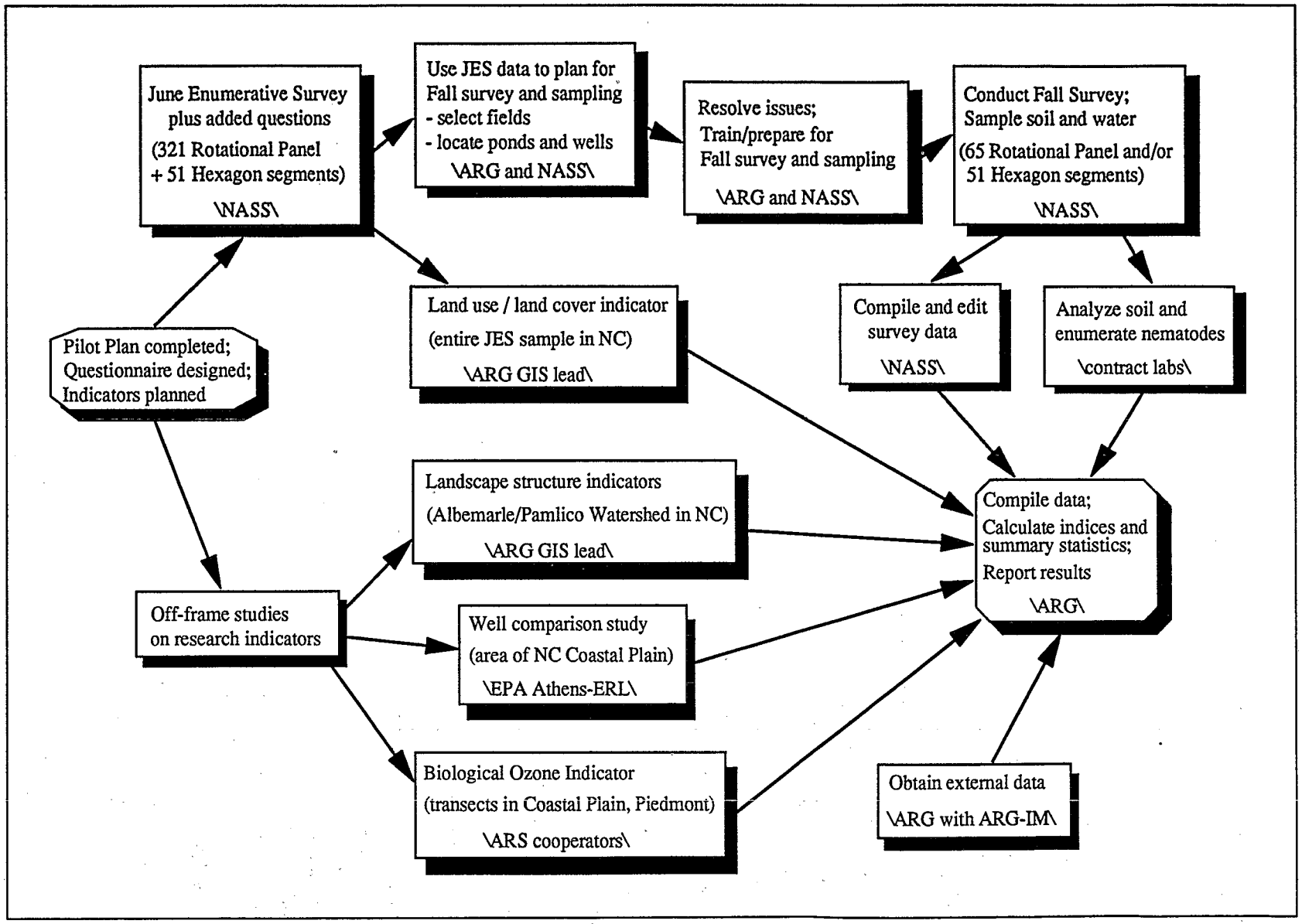



**Figure 8-1.** Major activities for the 1992 Agroecosystem Pilot.

with the ARG staff, which includes NASS personnel. Expertise in water analysis will be provided by the Athens EPA Environmental Research Laboratory (ERL).

Interagency agreements are in place between EPA and both ARS and NASS. Memoranda of Understanding are being developed between EMAP and both ARS and the Soil Conservation Service (SCS) to cover overall cooperation for the Pilot and beyond. The work of administering questionnaires and collecting soil and water samples will be done by NASS enumerators, hired on a part-time basis through the National Association of State Departments of Agriculture (NASDA). Most enumerators are local farmers, members of farm families, retired rural residents, or other persons with an interest in agriculture. They are located throughout each state, which expedites data collection and minimizes travel time and expenses. NASS will be responsible for hiring and supervising enumerators and will handle payroll and other administrative functions.

For the Agroecosystem Pilot there will be a slight expansion of the standard JES -- segments will be sampled on the EMAP hexagon design that would not otherwise have been visited [eight questions (7a, 10, 51, 51a, 51b, 52, 52a, 52b) have been added to Section D of the questionnaire]. In the fall, survey and sampling activities will require enumerators capable of the physically demanding work of sampling soil and water. It is most likely that individual enumerators will conduct field and well sampling, and that teams of two persons will handle pond sampling. Enumerators will operate according to NASS guidelines, including those regarding confidentiality, as well as procedures outlined in the manuals to be developed by NASS and the ARG. It is expected that at most 15 to 20 enumerators will be needed to collect the Pilot data.

One of the ARG members is also a professor in the Department of Plant Pathology at North Carolina State University. Permanent and hourly employees of his program, along with members of the ARG, will do the work of drying and grinding soil to be sent out for analysis. This effort is referred to as the "soil preparation laboratory."

Soil physical/chemical analyses and nematode counts will be done by contract laboratories. They are responsible for their own staffing. The Athens-ERL has the staff for analyzing water samples for chemical composition.

### *8.3.3. Design of Survey Questionnaires*

Two questionnaires will be used for data collection during the Pilot. The first will be the June Enumerative Survey (JES), an annual NASS activity to determine land use, livestock numbers, and crop stocks. The ARG will obtain land use/ land cover data from the JES (Section 5.4). In cooperation with NASS, the ARG has developed eight supplementary questions for the JES. Two of the questions specifically ask about land uses (irrigated acreage and idle cropland in government programs) not normally included in the questionnaire. Three other questions will help determine the presence and use of farm ponds. The last three will determine the presence and use of wells. These questions will be included in the entire North Carolina JES in 1992. A portion of the JES (land use page plus pond and well questions) will be conducted on the Pilot segments which were selected by the Hexagon Design (Appendix 5).

The ARG worked closely with NASS to design the Agroecosystem 1992 Pilot Study Questionnaire (i.e., Fall Survey), found in Appendix 5. This will provide data on crop yields, cropping sequence, fertilizer, pesticides, irrigation, tillage system and other management practices. These questions are geared toward the selected fields within the selected segments (see Section 3.3). There will be 65 segments sampled on the Rotational Panel Plan and 51 on the Hexagon Plan. These 116 segments are located in 83 of North Carolina's 100 counties.

### *8.3.4 Communications*

During surveys, communication will involve established NASS procedures for maintaining contact between the supervisory enumerator and the enumerators in the field. This will include reporting of work hours and mileage, progress of surveys, and similar information. For sample collection, additional lines of communication must be developed for sample tracking, general problems and emergencies.

*Sample and equipment tracking.* Each soil sample will have a unique identification code. As an enumerator sends each sample, he or she will also mail a postcard (Figure 8-2) indicating that the sample has been shipped and the date on which it was collected and mailed (Section 5.2.5). Room for special explanatory notes (e.g., "sample very wet due to recent rains") may also be provided. These postcards will be sent to the ARG Information Manager (1509 Varsity Dr., Raleigh, NC 27606). Some soil samples will go to the soil preparation laboratory at North Carolina State University, while others will go to the nematode enumeration laboratory. Logs of samples received will be kept at both locations. The possibility of using bar codes and computer software for sample tracking is being investigated.

Date mailed _____

Sample number _____ was collected on _____/_____/92 in _____ County and mailed to the nematode laboratory on the above date.

Enumerators: _____

==========(office use only)==========

Date received _____

**Figure 8-2.** Example of a sample-tracking postcard to be sent to the ARG by the enumerators.

The ARG will also record shipments of samples from the soil preparation laboratory (Raleigh, NC) to the contract soil analysis lab (to be determined). The analysis laboratory will keep a log of incoming samples sent to them and will report the samples they have received on a weekly basis. Similarly, weekly contact with the nematode enumeration laboratory will allow the ARG to keep track of the samples that have arrived there.

A scheme for tracking water samples will be developed in cooperation with the EPA-ERL at Athens, Georgia.

Equipment must also be tracked. Each piece of equipment (or each set of pieces, e.g., for soil probe accessories) will be marked "Property of the Federal Government" and enumerator kits will be numbered. Enumerators will sign for their equipment when received and again when returned.

*Emergencies and lesser problems.* Emergency communication in the field will be handled according to NASS protocol. The first priority is the health and safety of the enumerators; the communication policy should reflect this, providing for contact with police or sheriff, fire department, and ambulance services.

There are non-emergency problems which may arise in the field. Issues such as inability to locate a site or collect a sample will be handled through NASS. If an enumerator needs to replace lost or damaged equipment, he or she will be able to contact the supervisory enumerator, who will contact the ARG (Section 5.2.4).

### *8.3.5. Training*

NASS enumerators are part-time employees with a wide range of educational backgrounds. Prior to participating in any data collection efforts, they undergo an intensive training program in sample and data collection methods. Training of enumerators will be a joint responsibility of the ARG and NASS. It will be documented that successful training has been completed.

NASS will be responsible for enumerator training for survey questionnaires. A three-day training school will be held in Asheville, NC in mid-May for the North Carolina June Enumerative Survey (JES). NASS will have this year's Interviewer's Manual ready by that time. Training includes background information and a question-by-question review of the Survey instrument. Group and one-on-one practice exercises are conducted to strengthen the enumerators' knowledge of the questions.

A one-day training session will be held in Raleigh one week prior to enumerators going to the field in the fall. Earlier there will have been a practice training session with several enumerators, to identify weaknesses and make necessary changes in the training or procedures. NASS will be responsible for training enumerators for the collection of post-harvest survey data; the ARG, including members of the Athens-ERL, will train enumerators in soil and water sampling techniques. These techniques will be taught in the classroom and field. An

enumerator's manual for the fall collection of Agroecosystem data is being developed by NASS with input from the ARG. A first draft will be prepared by mid-August, with the completed version to be ready in October. It will include information on the background and objectives of the Pilot Project and will define specific interview and sampling procedures for the fall survey and sampling period.

### *8.3.6. Safety*

The safety of NASS enumerators must be a prime concern and must be considered in planning, in writing manuals and in giving training sessions. Conduct of surveys should not present any hazards that are unfamiliar to the enumerator, but soil, well, and especially pond sampling will require comprehensive planning. The safety issues are much less intense than for other EMAP resource groups which often sample in remote locations. Enumerators live in the same area that they work, so they should be aware of where such hazards as poisonous snakes, fire ants, and tick-borne diseases (e.g., Lyme, Rocky Mountain Spotted Fever) may be encountered. Common sense should guide decisions about dressing for the weather and working under extreme conditions (e.g., high temperatures, lightning storms).

Two areas will require special training: proper use of equipment and water safety. Trying to drive a soil probe into hard ground by repeatedly stomping on it can cause knee injury. This and other cautions need to be mentioned in the training session. Water safety will be covered for those enumerators who will be sampling ponds. Life jackets will be required of all those sampling ponds, even if the enumerator is working from the bank. Those using boats will be instructed in their proper care and use. Finally, all enumerators will wear blaze orange vests (or orange life jackets) while taking soil or water samples because the sampling period coincides with the deer hunting season in North Carolina.

Three other areas need to be discussed with NASS before a decision is made to include them in the safety plan and training. (1) According to the *Guidelines for Preparing Logistics Plans*, "First aid and CPR training are required for all personnel, especially those who will be working

in remote locations" (Baker and Merritt 1991, Section 2, Page 11 of 20). The guidelines also say that the safety plan is supposed to designate the American Red Cross First Aid textbook as a guide for first aid and CPR. Whether these are binding directives and how they should be applied within the Agroecosystem Program must be investigated. (2) During NASS Objective Yield Surveys, enumerators work in fields of standing crop; therefore, pesticide safety is a part of their training (USDA-NASS 1991b and 1991c). It will be discussed with NASS whether this is warranted for the type and timing of the sampling that will be done for the ARG. (3) A policy may need to be developed for the unlikely event that an enumerator runs across a marijuana field, moonshine still, poaching, or other illegal activity.

The soil analysis and nematode enumeration laboratories will be contractors, responsible for their own safety plans. The soil preparation laboratory is an activity run through the university research project of one of the ARG members. Safety will be the responsibility of that scientist and his technician. Chemical analysis of water samples will be done at the U.S. EPA Environmental Research Laboratory, Athens, Georgia. That laboratory also has its own safety plan.

### *8.3.7. Sampling Schedule*

Data will be collected by NASS enumerators for the ARG during the June Enumerative Survey and during survey and field visits in the fall. The period of field activity for the JES is mid-May to mid-June. Administering the Agroecosystem questionnaire and taking soil and water samples will be done from November through early December. NASS will be responsible for the development of detailed sampling schedules within each survey or sampling period.

### *8.3.8. Site Access and Reconnaissance*

NASS has an excellent record with the agricultural community at the national, state, and local levels. Obtaining permission for site access is rarely a problem. During the JES, enumerators locate and interview all farm owners or operators in sampled segments. From

special questions added to the JES, the ARG will know whether farm ponds or wells are present on the segment and what they are used for. During the Fall Survey, enumerators will solicit permission to collect soil and water samples.

Physical access to fields and wells should not be difficult, but thick brush or muddy banks may hinder access to certain ponds. Therefore, the pond to be sampled should be visited immediately after permission is obtained, to determine if such problems exist and to make necessary preparations. Enumerators should not cut brush or otherwise disturb the site. Enumerators will keep notes on any problems they encounter, such as impossible access.

### *8.3.9. Procurement and Inventory Control*

The ARG will provide equipment and supplies for the collection of soil and water samples and for the transportation of samples to contract analytical laboratories. NASS will provide all survey instruments and supplies (e.g., aerial photos) associated specifically with the questionnaires. A list of the equipment to be found in the soil sampling kits is found in Section 5.2.4. At least 12 such kits will be needed for the Pilot. Four soil probe sets are already on hand, but they are not yet marked "Property of ----------" or numbered. Types of mailing containers will be chosen after a soil analysis laboratory is selected and after consultation with NCDA about rules for shipping soil from quarantined areas. Soil samples sent to the nematode laboratory will be enclosed in a padded envelope, lined with bubble-wrap, to minimize the impact of sample handling on nematode viability. Pre-printed labels for each sample will be produced by NASS in consultation with the ARG.

Probes and other soil sampling equipment for the Pilot will need little storage space and will be kept at or near the ARG headquarters in Raleigh. Enumerators will sign out equipment and receive supplies at the training session. Equipment will be returned at the debriefing following the Pilot. Enumerator kits for water sampling will be more complex, especially since boats are to be used. Procurement and inventory of this equipment will be developed in conjunction with the Athens-ERL.

### *8.3.10. Field Operations*

NASS will be responsible for all data and sample collection activities during both the June Enumerative Survey and the Fall Survey. The ARG will be responsible for all field activities involved in the development of new indicators during the initial stages of testing. (See logistics subsections in Sections 5 and 6.)

*Surveys.* Survey logistics will be the responsibility of NASS, which has years of experience in this area. NASS uses specialized computer software to track the progress of their surveys. Details on how the enumerators are to conduct the surveys will be found in the manuals which will be developed for both the JES and the Fall survey. For an example, see the *Interviewer's Manual* for the 1991 JES (USDA-NASS 1991b). The period of field activity for the JES is mid-May to mid-June. The Fall Survey and associated sampling will take place from November to early December. Questions on the Fall Survey will be directed toward individual fields. NASS and the ARG Statistics Group will select the fields, using the scheme described in Section 3.3.1, and will outline them on aerial photographs that will be given to the enumerator.

*Soil sampling.* Soil and water sampling will be done during the same period as the Fall Survey. To save time and travel, soil samples will be taken right after the questionnaire is completed and permission is obtained. Water may or may not be sampled during the same visit. Soil sampling will be done as outlined in Sections 3.3.2, 5.2.4, 6.1.4 and Appendix 6. A very brief description is presented here.

The field will be sampled with 20 soil cores taken at equal distances along a 100-yard transect. Enumerators will have the aerial photographs, sampling equipment (including probes, bags, labels and mailers) and the number of paces (printed on a label on the survey form) needed to locate the transect midpoint. This midpoint will be determined using a modification of the NASS method for locating objective yield plots. The enumerator will take the assigned number of paces along and into the field, and will orient the transect at a 45° angle to his or her path of entry into the field. Samples will be taken at five-yard intervals along the transect. The 20 cores

will then be composited and mixed. Soil clumps are to be broken apart gently. Samples for soil analysis (500 $cm^3$) will be drawn from the composited sample, labeled, and packaged. The enumerator will ship the samples that same day or early the next day via Federal Express (call 1-800-238-5355 for pick-up) to the Soil Preparation Laboratory at N.C. State University. Postage will be paid using a Federal Government account through the Air Resources Research Consortium at N.C. State University. Delivery on weekdays and weekends should be requested on the mailing label. Subsamples for nematode determination (550 $cm^3$) will be drawn from the composited samples from fields on only one of the two sampling designs (Rotational Panel Plan). These subsamples must be kept in an insulated box (ice chest) away from extreme heat or cold until they can be shipped to the enumeration laboratory. They should be sent between Monday and Thursday so that they reach the laboratory on a weekday. If this is not possible, the enumerator will notify the laboratory so that the sample can be handled properly when it does arrive. After shipping any sample, the enumerator will complete and mail the sample-tracking postcard to the ARG Information Manager (see Figure 8-2). Procedures for labeling, handling and tracking samples are still being developed by the ARG with input from NASS.

A preliminary test of soil sampling procedures showed that samples shipped via Federal Express on Monday-Thursday from various points in North Carolina reached the destination laboratories in Raleigh, NC and Corvallis, OR in one or sometimes two days. During the study, the time needed to actually sample a diagonal transect (starting at the end, not the midpoint) averaged 22 minutes.

*Water sampling*. Methods for sampling, handling and transporting water samples are not yet finalized (Section 5.3). It is also not yet known which analytes are to be measured and which segments will be selected for pond and well sampling. JES data will be the basis for selecting ponds and wells within segments (Section 3.3.4). This may be done before the enumerator goes out, or the enumerator may have to make the selection in the field.

There are two pond sampling methods under discussion (see Sections 3.3.5 and 5.3.2). The standard method requires a boat. A logistically easier "bank" method will be tested, and

compared to the "boat" method. The "bank" method will involve the use of a long pole (~16 feet) that allows an enumerator on the bank to lower a sampler into the pond. Multiple water samples from each pond will form a composite sample from which analysis samples will be taken. Water samples from wells will be easier to take, but must only be taken after an appropriate purge (Section 5.3.2).

Once the list of analytes has been chosen, detailed water sample handling procedures will be developed. Samples will need to be shipped in amber glass containers within insulated cartons. Also, instant cold packs will be used to keep the samples near 0°C (Section 5.3.4). The EPA Region IV SOP manual (U.S. EPA 1991b) will be the guide for water sample handling (Section 5.3.2). Samples will be shipped overnight express (Federal Express) directly to the Athens-ERL. Methods of identifying and tracking samples have yet to be developed. Procedures for return of equipment must also be discussed.

### *8.3.11. Laboratory Operations*

Procedures to be used at the soil preparation laboratory (N.C. State University) are found in Section 5.2.4 and Appendix 4. As samples are received, they will be logged in and spread in metal pans to air dry. Once dry, soil will be ground in a hammer mill and mixed thoroughly. Subsamples will be sent to the soil analysis laboratory, and the remainder of each sample will be archived in case re-analysis is needed. Two subsamples will be taken from some of the samples, as a check of the analysis laboratory's precision.

The analysis laboratory has not yet been selected, but will be asked to test the soil using the procedures listed in Table 5.2-11. Detailed laboratory procedures are described in Appendix 4. Log books for sample tracking will also be required.

Information on procedures for nematode enumeration are given in Section 6.1.4. The nematode enumeration laboratory will log in samples and store them at 15°C. Samples will be processed within 14 days of receipt. From each sample, 50 $cm^3$ will be used for gravimetric

determination of soil density and moisture content. The other 500 $cm^3$ will be used for nematode extraction by elutriation. Nematodes will then be identified to trophic group. The laboratory of Dr. K.R. Barker, NCSU, will handle nematode extraction and enumeration for the Pilot.

Water samples will be analyzed for contaminants at the Athens-ERL. The techniques to be used will depend on what chemical species are of interest (see Sections 5.3.5 and 6.3.5).

### *8.3.12. Waste Disposal*

*During sampling*. There are few hazards associated with the soil or water samples, but some precautions need to be taken. Soil should be cleaned from probes, buckets, and other items before the next field is visited. This will reduce the chance of spreading weeds, nematodes, and other soil-borne pests. It is especially critical in areas under quarantine for witchweed (*Striga asiatica* Lour.) or imported fire ant (*Solenopsis invicta* Buren). NASS has a compliance agreement with federal and state authorities responsible for quarantines. This may need to be expanded to include soil samples. Soil from all counties will be treated and packaged as if it came from quarantined areas.

Certain lakes in Wake County and a few isolated bodies of water in 11 other counties contain hydrilla (*Hydrilla verticillata* (L.S.) Royle), a noxious aquatic weed (Gene Cross, NCDA, personal communication). After taking pond water samples in these counties, enumerators should remove all weeds that may have stuck to the sampling equipment, including the boat.

*At the laboratories*. The first disposal issue for the laboratories is that they not discard any sample too soon. The soil preparation and analysis laboratories will be required to archive samples until data have been determined to meet quality objectives (Section 5.2.5 and Appendix 4). Some extracted nematodes will be preserved and stored, in case more detailed identification is needed (Section 6.1.5).

All laboratories handling soil samples from the Pilot will be required to follow specified procedures before disposing of soil from areas under quarantine for witchweed or imported fire ant. These procedures specify the temperature and duration to heat the soil (or soil screenings) to kill the pests. The soil preparation laboratory, run by the ARG, will sign a compliance agreement with the Animal and Plant Health Inspection Service (APHIS) and the North Carolina Department of Agriculture (NCDA) guaranteeing that the procedures will be followed. The nematode and soil analysis laboratories will be chosen from among a list of laboratories that follow acceptable protocols.

Witchweed and fire ant quarantine counties are located in southeastern North Carolina, though many of these counties are only partially under quarantine. For simplicity, the contract laboratories will handle all samples as if they came from quarantined areas.

Waste disposal of any other hazardous materials, such as reagents used to test soil, at analytical and enumeration laboratories is to be done in a responsible way according to the methods generally used by those laboratories.

### *8.3.13. Information Management*

Data collected during the Pilot, as well as massive amounts of existing data (e.g., Natural Resources Inventory, Agricultural Census, State Soil Survey Database, weather data, GIS data) will need to be managed by the ARG Information Manager, through the Agroecosystem Information Center (AIC). Cooperation with NASS and the logistics of managing data transfer between NASS and the AIC are being developed. Pilot Survey data will go first to NASS, while soil and nematode analysis data will come first to the ARG. A critical concern is to ensure the confidentiality of data from individual farms. These issues, along with hardware and software requirements, are covered in Section 9. Some of the logistics for the acquisition of the data to be used for land use/ land cover and landscape descriptors are covered in Sections 5.4, 6.2.3 and 6.2.5. These include data from satellites and possibly aerial photography.

An additional information/logistics issue is how to report back to the farm operators. They should be given the results of surveys and analyses. One question is how much of an interpretation should be put on the results. Giving raw numbers may be meaningless, so some interpretation is needed. Should it go so far as to recommend remedial measures for problem situations, or refer the farmer to sources of such recommendations? Even negative results can present a problem. A farmer might assume that his well or pond is certified free of contamination just because there were no detectable levels of the contaminants which were of interest for the Pilot (observation of Dr. W. Payne, Athens-ERL).

### *8.3.14. Quality Assurance*

A streamlined logistical operation helps to ensure that data are collected properly and that good records are kept. Also, a number of QA procedures for the Pilot will have to be incorporated into the logistics area. Some of these are already part of NASS operations (eg., the work of supervisory enumerators and call-backs to verify questionnaires). Others are sampling operations that will be added for QA purposes. For example, a second composite soil sample will be taken from every sixth field. Half of those second composite samples will contain 40 soil cores, two from each point on the transect. This larger sample has enough soil that it can be split at the preparation laboratory and sent as duplicate samples to the analysis laboratory. Section 7 gives further details on Quality Assurance for the 1992 Pilot.

### *8.3.15. Cost Tracking*

One of the objectives of the Pilot is to compare the efficiency (cost and precision) of the NASS Rotational Panel and the EMAP Hexagon Design (Section 3.2). To be sure that every applicable cost is included, each step in the survey process for each Plan will be identified and placed in its proper sequence in a flow chart. Information on costs will be recorded by NASS for every step in the Pilot: frame development, sample selection, preparation of maps and aerial photographs, and conduct of the sampling and surveys. Some of these are discussed in Sections 3.1.1, 3.1.2 and 3.2.1. It is standard practice for NASS enumerators to report their time and

mileage during surveys, but the cost of office work by NASS will need to be included. Allowance will be made for the fact that certain activities (e.g., soil sampling for nematodes, water sampling) will be done only on one design or the other. Costs of conducting each NASS survey are reported in the "Survey Administration Analysis" (see below). The difficult part will be estimating costs (per track and per segment) attributable to the EMAP Hexagon Design.

### *8.3.16. Review of Logistics*

During the Pilot Project several reviews of the logistic plan and procedures will be conducted. Members of the ARG, NASS, and the EMAP Technical Coordinator for Logistics will participate in these reviews. The purpose of the reviews will be to identify areas of missing information associated with the monitoring program and procedures for incorporating this information; also, to re-examine all phases of the logistics plan.

After the Pilot, enumerators will be debriefed to determine strengths and weaknesses in the logistics. Enumerators will return sampling equipment at this time. A post-Pilot meeting will also be held with NASS administrators. A Logistics End-of-Season Summary Report will document problems and propose solutions.

Within 12 months of each survey conducted by NASS, a report called a Survey Administration Analysis is produced which contains specific information about the survey (i.e., response rates, cost accounting). Estimated completion dates are November 1992 (for the previous JES) and August 1993 (for the Pilot Fall survey).

## 8.4. Logistics for the Biological Ozone-Indicator System and the Well Comparison Study

Logistics for two aspect of the Pilot have not been documented above: the use of ozone-sensitive and ozone-resistant clones of white clover (*Trifolium repens* L.) as biomonitors and the comparison study of existing wells with research wells. These projects will be conducted in a slightly different way from the rest of the Pilot. The ozone biomonitor system will be tested in

conjunction with the Cooperative Extension Service, and plants will be deployed in the North Carolina coastal plain and piedmont. This design is still being developed. Logistical details may be found in Section 6.4.

The well study will compare the chemistry of groundwater samples taken from existing wells with the chemistry of water from specially drilled research wells. The goal is to determine if there is a bias in samples taken from existing wells. This study will be performed by members of the Athens-ERL in a selected area of the coastal region of North Carolina. A full description may be found in Section 6.3, with logistics details in Sections 6.3.2 and 6.3.4.

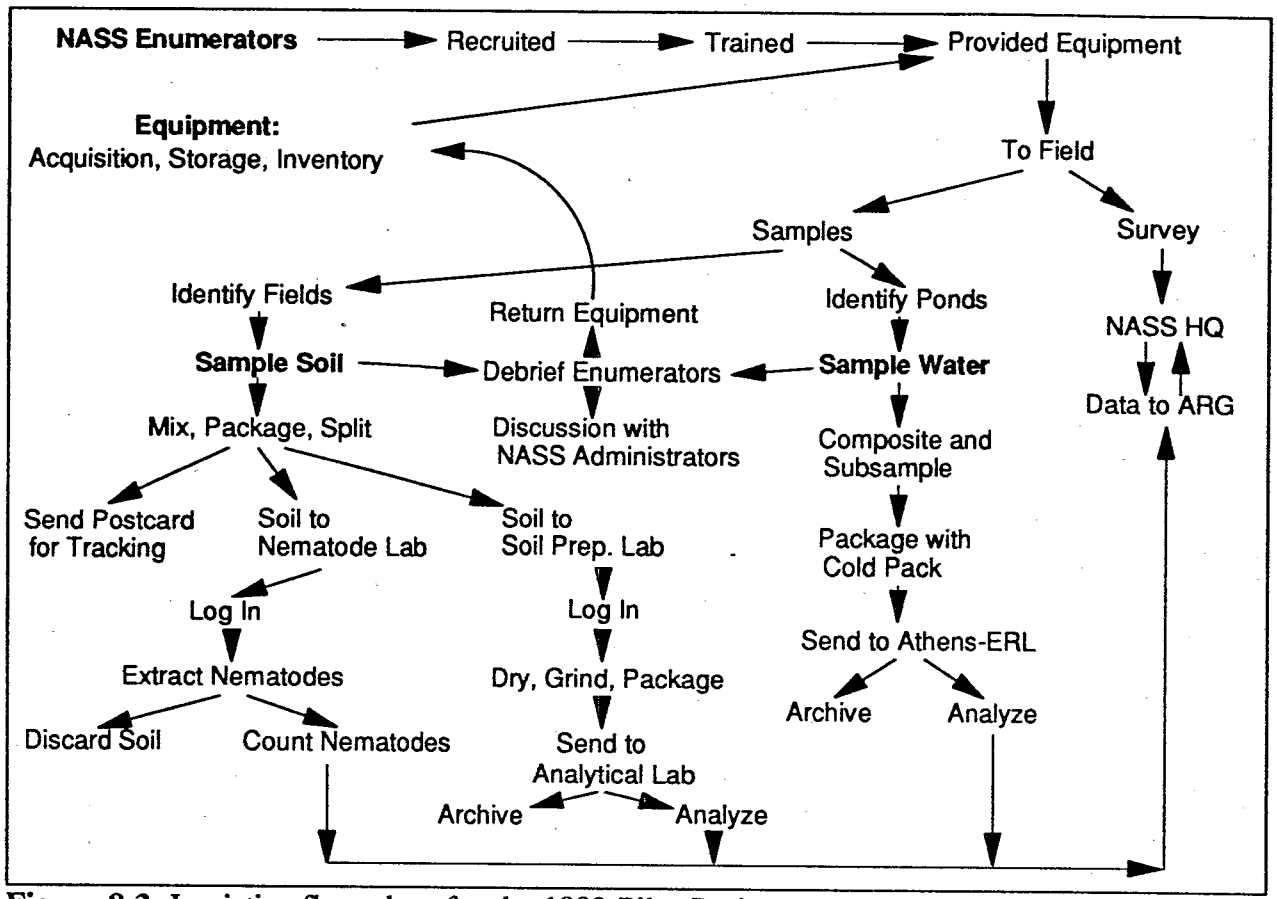



**Figure 8-3.** Logistics flow chart for the 1992 Pilot Project.

# 9. Information Management

## 9.1. Introduction

The Agroecosystem 1992 Pilot Project will require that data be obtained, stored, manipulated, integrated and analyzed. These new and existing data will come from many sources, including joint ARG-NASS data collection efforts and from other EMAP Resource Groups, other government agencies, cooperating non-governmental organizations (NGOs), and academic institutions (Figure 9-1). The information collected, together with existing data, must be integrated in such a way as to make meaningful analysis possible. The focal point of this integration will be the Agroecosystem Information Center (AIC). The AIC will be developed during the Pilot to provide computer equipment, data storage, data processing, software development and data communications facilities to the ARG.

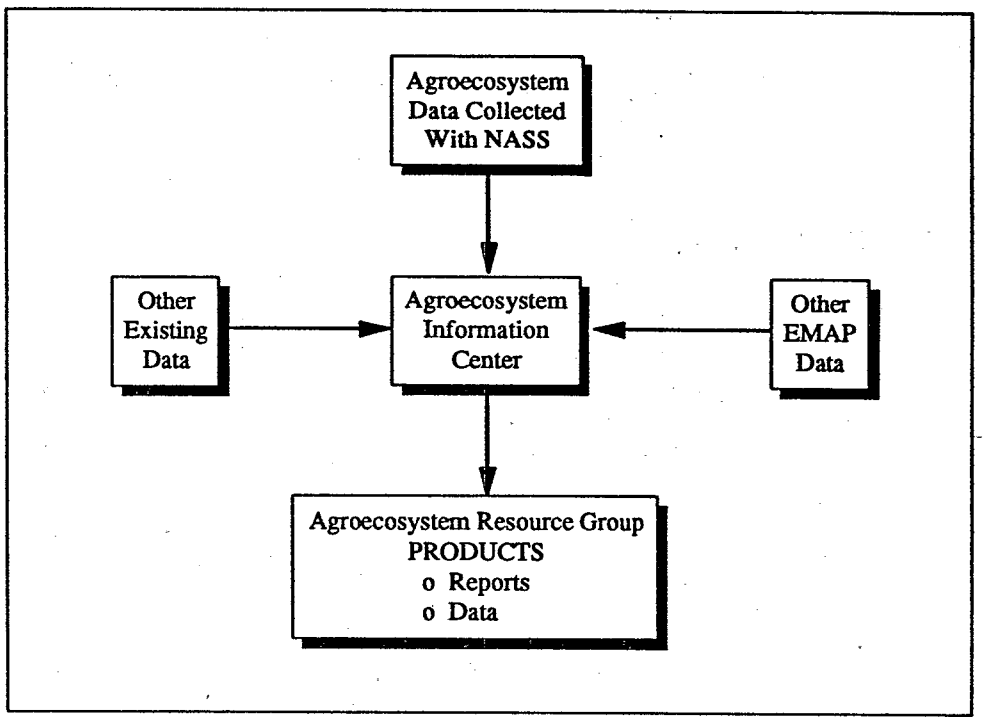



**Figure 9-1.** Overview of the flow of data through the AIC

A major emphasis of the Agroecosystem Pilot Project is the development of a close working relationship with USDA-NASS (Section 1.2). As discussed in Section 3.2, NASS uses an area frame to gather data on crop acreage, cost of production, farm expenditures, crop yield, specialty crops, livestock production, chemical usage, irrigation, water quality and other items of interest to the agricultural community. Statistics are compiled and reported annually from the June Enumerative Survey (JES) using some 16,000 Primary Sampling Units nationwide. A primary objective in the Pilot will be developing and fine tuning the logistics and cooperation required for moving and integrating data from several sources into a data management system that is available to the ARG. Group members will perform statistical, modeling, geographical and other types of analyses, using the data.

Confidentiality of data, and consequently data security, are particularly critical issues to the ARG/NASS relationship. Meeting the program objectives requires that data be collected from individual farmers and corporations. Because these NASS data, at some level of summarization, are then to be available outside the confines of NASS facilities, there must be a policy and mechanism which continues to protect the privacy of the individual respondents. As a part of the Pilot, the ARG will work closely with NASS to establish methods and procedures for maintaining strict confidentiality and security of all microdata (i.e., data which can be associated with individual growers and operations).

## 9.2. Information Sources and Flow

Information that will be used for analyses and reporting in the pilot will originate from two general sources: those data actively collected at the farm field sites and those existing data (both current and historical) that have been collected by other agencies.

Data for the 1992 Pilot will be collected under an Interagency Agreement developed with USDA-NASS under which NASS enumerators collect all of the agricultural field level information. This information will consist of both survey data and physical samples for laboratory analysis (Figure 9-2). The enumerators will operate within the NASS organization,

using procedures selected and developed jointly by the ARG and NASS. The survey data will be entered, verified, validated, and stored on NASS computers. The soil laboratory data will be sent as an ASCII file to the ARG Information Manager. The ARG Information Manager will perform validation tests on the data. Once validation is complete, the laboratory data will be sent to NASS for integration with the survey data. Only aggregated or summarized data will be transferred to the AIC within the constraints of NASS confidentiality agreements.

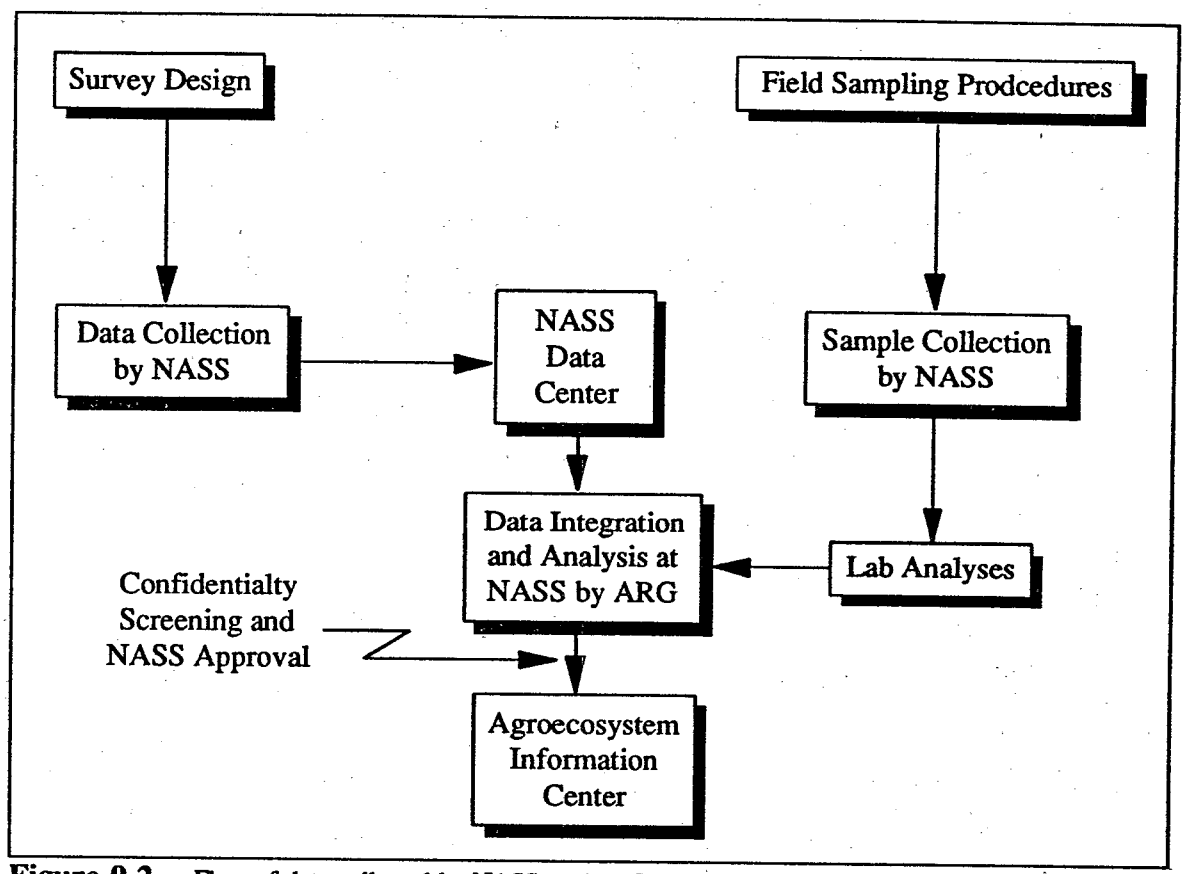



**Figure 9-2.** Flow of data collected by NASS to the AIC

From the standpoint of information management, working with NASS is important for a number of reasons.

- Over time, NASS has developed a relationship with the agricultural community which will greatly facilitate the collection of data.

- NASS provides the assurance of data confidentiality to individual farm operators. This allows the organization to collect data which farmers might otherwise be reluctant to supply for fear of legal or regulatory action.

- NASS has a fully developed infrastructure for the collection, recording, summarization, analysis and publication of agricultural data, including strict quality controls. Use of this infrastructure greatly reduces the expenditure of resources on the development of duplicate logistics and QA procedures.

- NASS has developed the computer resources to organize, analyze, and quickly report on large volumes of data. Use of these resources may reduce the overall need for data processing within the ARG.

In addition to field data, a broad array of existing data will be required for the 1992 Pilot Project (Figure 9-3 and Table 9-1). The ARG is committed to the use of existing data whenever possible, assuming the scope and quality of the data are sufficient for our needs. Although there may be some effort required to transform existing data to conform with EMAP standards, this effort is usually substantially less than that required to collect new data. The existing data we anticipate using, fall into two major categories and have a variety of uses. These are:

- Physical and biological parameters: used to provide complementary data, verify values of collected data, provide a basis for the implementation of summarized data (validation), and for indicator research.

- Geographic based data: used for boundary establishment, provide spatial distributions, perform geographic visualization, and for indicator research.

The physical and biological data, although distinct from geographic data, are frequently associated with one another in the same database. This is often referred to as geo-referenced data. For example, meteorological data, which are critical to the development and interpretation of any crop yield or productivity measures for an area, are associated with a collection point. The use of existing data also permits the analysis of historical trends. In this way, it may be feasible to validate and correlate measurements associated with specific endpoints by predicting

present conditions using historical data. Existing data will be used to develop expected values for performing verification and validation of both survey and sample data (Figure 9-4). The ARG will import data as needed and appropriate from other EMAP efforts as well as other agencies and organizations to support pre- and post-Pilot activities.

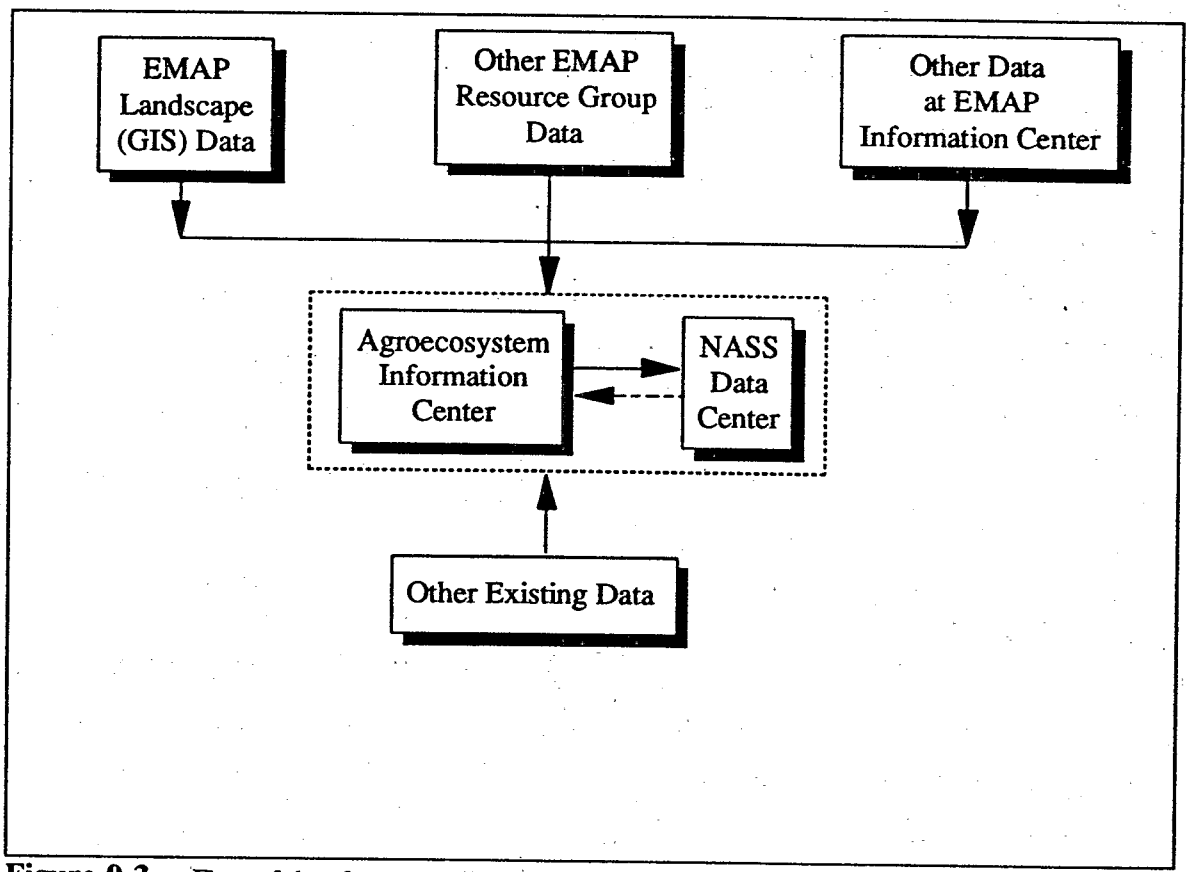



**Figure 9-3.** Flow of data from other EMAP sources and other agencies and institutions to the AIC and NASS data center for integration

## 9.3. Confidentiality of Data

In order to protect the rights of individual respondents, legal confidentiality provisions (Table 9-2) apply to all data collected by NASS. The NASS cannot release microdata; data are currently available, in most cases, at the county level. The United States Department of Commerce's (USDC) Census of Agriculture is also legally subject to confidentiality provisions, and the USDA Soil Conservation Service's (SCS) National Resource Inventory (NRI) follows confidentiality

**Table 9-1.** Examples of existing data to be used for the 1992 Pilot Project.

| Description | Source |
|---|---|
| Weather and Climate Data | NOAA |
| State Soil Survey Database (N.C. derivation of SOILS-5) | SCS |
| National Resources Inventory | SCS |
| Herbicide Use Database | Resources for the Future |
| Ag. Land Use and Cover Data | NASS |
| Census of Agriculture | USDC |
| Soil Ratings for Pesticide Loss | BRG/Data & SCS |
| Major Land Resource Areas | SCS |
| Albermarle-Pamlico Watershed Coverages | NCCGIA |
| Aerial Photography | ASCS |

restrictions. Table 9-2. summarizes some of these policies. The rationale behind such assurances is clear. Confidentiality laws protect individual respondents from prosecution which might otherwise result from their participation in a data collection effort. Without such assurances, respondents may be hesitant to comply with any survey or data collection efforts, either voluntary or legally required. Also, without these assurances, respondents may be more likely to falsify information on surveys. Violation of this confidence would result in loss of NASS credibility with survey respondents and seriously hamper future data collection efforts. Hence, NASS is very serious about maintaining data confidentiality.

The current view of the ARG with respect to these confidentiality provisions is positive. In a review of confidentiality in EMAP, Franson (1990) writes that the EPA is presently unable to issue a blanket statement of confidentiality for EMAP data. Requests for EMAP data from the

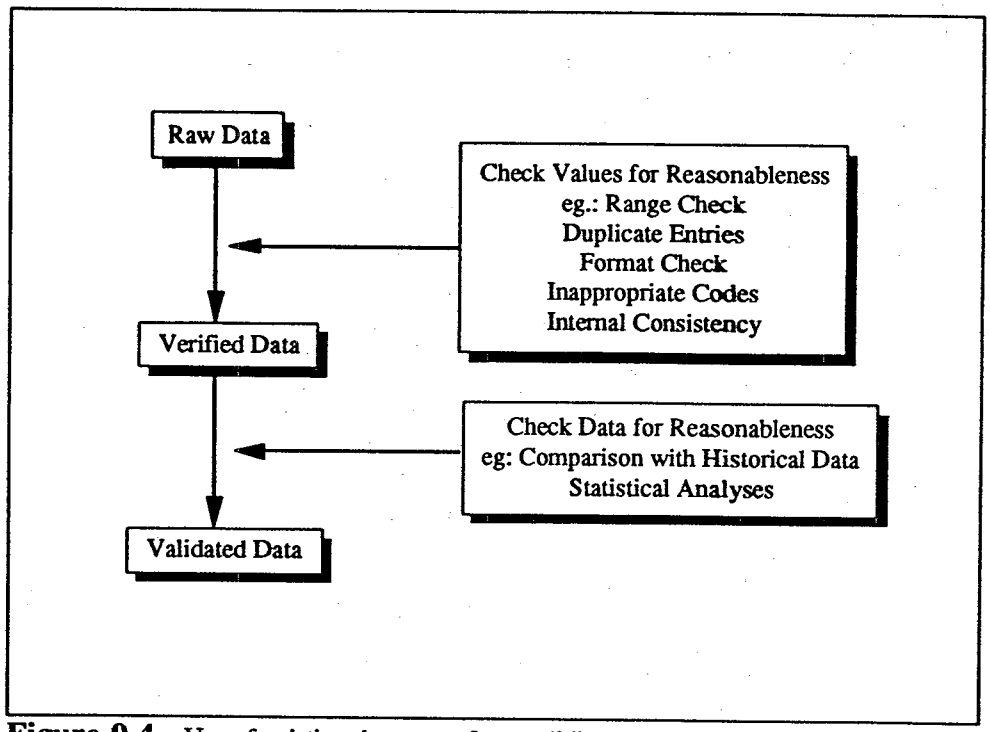



**Figure 9-4.** Use of existing data to perform validity checks on data

regulatory arm of EPA, or from other agencies, corporations, and individuals, must be reviewed on a case-by-case basis. Farmers are unlikely to provide data without a confidentiality agreement. In fact, the question of whether farmers would cooperate with any team identifying themselves with the EPA, even with promises of confidentiality, should not be lightly dismissed.

Although the microdata from agencies employing confidentiality provisions are not available, there are solutions which allow the ARG to make use of the data collected by NASS.

***Aggregated data:*** Whereas many agencies will not release their microdata, they will all release data aggregated at various levels (Table 9-2). The goal is to aggregate the data in such a way that individuals cannot be identified. Obviously, for the Agroecosystem Program, the lower the level of aggregation, the better (i.e., county-level data are better than state-level data.)

**Table 9-2.** Summary of confidentiality provisions of several government agencies with data of value to the Agroecosystem Resource Group.

| Organization | Policy | Lowest Level of Aggregation Normally Available |
|---|---|---|
| USDA National Agricultural Statistics Service | Public Law 99-198. No release of data with identity of individual respondent. | County |
| USDC Census of Agriculture | US Code Title 13. No release of data with identity of individual respondent. | Zip Code (5 digit) |
| USDA Soil Conservation Service (National Resource Inventory) | No release of exact location (Primary Sampling Unit) at which data are collected. | County |
| US Environmental Protection Agency | Freedom of Information Act requests handled on a case-by-case basis. | Varies |

***Analysis requests:*** The owning agency may accept requests for tabulation and analysis from another agency. The analysis would be performed by the owning agency's personnel, the results returned to the requesting agency. Release of any confidential material would be strictly avoided.

***Deputization:*** It is possible, at least with some government agencies (including NASS), for an individual to be deputized by that agency. Deputization requires completion of a non-disclosure agreement. A deputized individual is permitted to access the data for the purpose of performing analyses. Typically, the analysis would have to be performed at the owning agency's facilities. Only aggregated results may be removed, and are subject to confidentiality screening.

All of these possibilities will be explored by the ARG with NASS, and any other agencies with such provisions, during the Pilot program. Currently, the view of the ARG is to treat this as a true Pilot Project; data will not be released, in any form, to anyone outside of the EMAP until it has been summarized into a publishable format. Regardless of the confidentiality provisions, it is our belief that because of the preliminary nature of these data, they would not be of use to others, except in a final publication format.

## 9.4. Data Integration and Management

The integration of EMAP data with data subject to confidentiality provisions presents a unique challenge that can be resolved only through close interagency cooperation. The NASS data are used for economic forecasts which have the potential for affecting the livelihood of many people. They are closely guarded and access is severely restricted and carefully monitored. No microdata may be removed from NASS facilities, and computers containing microdata may not be connected to foreign networks. During the pilot program NASS will allow the ARG to install a workstation at the NASS facilities in Raleigh, NC. ARG members will be able to examine and analyze NASS microdata using the workstation. Integration of data from other sources may be accomplished by loading that data onto the ARG workstation at the NASS facilities and performing the required analyses on that workstation (Figure 9-3). Although this mode of operation will suffice during the pilot program, other approaches will be explored for future pilots, demonstrations and implementations.

Because of the data confidentiality and security requirements discussed previously, the task of data management becomes paramount. In order to coordinate and facilitate the movement, integration and selection of collected and ancillary data, a full-featured relational database management system (RDBMS) must be employed. This becomes especially critical when ARG members require different "views" of the data so that different analyses can be performed on various subsets. Carefully constructed data dictionaries are essential to maintaining flexible access to all of the data. Another important concept to be established and tested during the pilot is that of maintaining metadata associated with the collected data. These metadata will provide different characteristics of the data (i.e., collection methods and units), which will furnish invaluable information when the data are evaluated in the future.

## 9.5. Data Access

Providing ARG members access to the pilot and ancillary data in a convenient and organized manner will prove to be the foremost challenge of the AIC. Individual ARG members are

currently located in several cities throughout the United States (Appendix 1). Because of the requirements for data storage locations (Figures 9-2 and 9-3), the logistics of locating, accessing and transporting that data to the individual investigator will require a carefully planned and designed information system.

Although we anticipate no release of pilot data outside of EMAP, eventually aggregated data from demonstration projects and implementation will be made available to outside groups and agencies. This will necessitate identifying what is available, where it is located, its characteristics (metadata) and how to obtain it. Development of this reference, the data catalog, will be a component of the Pilot Project. Plans call for working cooperatively with the Information Management Committee (IMC) of EMAP, which is attempting to standardize the process for cataloging EMAP data.

## 9.6. Hardware and Software Requirements

In order to establish and further develop the AIC in support of the Pilot, additional hardware and software procurements are anticipated. Listed in Table 9-3 are the items of major significance that the ARG will purchase to use in the 1992 Pilot. Not listed in the Table are the smaller items (i.e., software and computing supplies). Although a great deal of thinking has gone into planning the AIC, unexpected situations can arise that change the data processing requirements of the group. One such situation is the need of the ARG for ancillary data. The size of the datasets and computing resources required for their transformation and integration are not completely known at this point. As indicated in Table 9-3 a substantial upgrade of both disk and tape capacity is planned in response to increased data storage requirements.

Two more workstations will be needed for the pilot. One of these will be located at the NASS data center office for analyzing and aggregating confidential data. Additional personal computers will be purchased for staff that currently are lacking them. Because of the travel that will be involved with the Pilot, a notebook computer for the ARG will prove a valuable resource for documentation and communication.

Several software requirements are critical to the success of the Pilot. A major upgrade of ARC/INFO is expected in early 1992. This upgrade will provide a point-and-click interface as well as other changes to improve ease of use. An additional copy of ARC/INFO and SAS will be required for the workstation at NASS. In order to allow adequate time for software development and testing, a RDBMS must be procured soon. At this time, EPA has not awarded the contract for the RDBMS.

Planning is currently underway for the installation of a local area network (LAN) for the ARG facility in Raleigh. The LAN will provide more convenient access to, and faster movement of, the data associated with the Pilot. Preliminary plans call for attaching the LAN to the Internet via the North Carolina State University campus fiber optic backbone. This connection will permit the Raleigh location to exchange data and information with ARG members at other sites and with the EPA laboratories. This link will be invaluable to the ARG during summarization and assessment activities of the Pilot. With the Internet connection established, ARG members all over the country will have interactive access to the AIC. In the future, when the EMAP Information Center (EIC) will become the repository for ancillary data and resource group data, the link will permit interactive uploading and downloading of data from other resource groups and cooperating agencies.

**Table 9-3.** Hardware and software requirements to support the 1992 Pilot Project.

| Item | ARG (Varsity Drive, Raleigh) | ARG/NASS HQ (Raleigh) |
|---|---|---|
| **PC and Workstation Requirements** | Development workstation<br>80386 PC (2)<br>Notebook PC | GIS workstation<br>80386 PC |
| **Peripherals** | 1.2 Gb Disk Drive (2)<br>4mm DAT Tape Drive<br>CD/ROM Drive | Plotter |
| **Major Software Requirements** | RDBMS<br>ARC/INFO upgrade<br>ARC/INFO GRID module<br>ARC/VIEW module | ARC/INFO<br>SAS |
| **Telecommunications Requirements** | LAN for ARG<br>Connection to Internet | |

# 10. Resources and Implementation

## 10.1. Introduction

The Agroecosystem Resource Group (ARG) has developed a five year program strategy (Heck et al. 1991) for implementation of a suite of indicators for monitoring agroecosystem status and trends. This five-year period (1991-1995) includes time to test concepts relating to design, indicators, data analysis, QA, logistics and information management at the pilot and demonstration program stages. A primary emphasis is the development of close working relations between personnel from NASS and the ARG, so that issues relating to design, QA, sampling, logistics, information management, and data analysis can be identified and addressed.

The first stage of the program (1990) encompassed the evaluation of: 1) statistical designs, 2) existing monitoring programs (i.e., NASS, SCS, ERS), 3) assessment endpoints and associated indicators (availability, validity, variability, cost), 4) data management and analysis techniques and 5) derived outputs. During 1990, a conceptual national monitoring plan was also developc . The second stage involves the design and execution of pilot and demonstration projects prior to implementation. The 1992 Pilot Project in North Carolina, will test all aspects of the monitoring program for a selected suite of indicators. Results will be utilized to develop a regional demonstration of all program elements in the Southeast (SE) and a Pilot in EPA Region 7 for 1993. The pilot and demonstration projects will address specific concerns of the different geographic areas of the country.

This Section addresses specific budgetary and personnel resources, and tasks planned for the 1992 Pilot. The Section does not address details as to how the various tasks and plans for the Pilot will be accomplished, since the details are contained in earlier sections of this Plan. Timelines are not included in this Plan for the Pilot but are being developed by ARG members for inclusion in the 1993 Demonstration/Pilot Plans.

This section briefly addresses activities and budgetary and personnel resources required to proceed with a full Southeast (eight state) Demonstration and a full Region 7 (four state) Pilot in 1993.

## 10.2. Importance of the Pilot

It is essential for this Pilot Project to be considered a research Pilot with sufficient flexibility to try a number of innovative approaches to all facets of the Pilot. This is important, if we are to continually improve the various components of the monitoring approach in preparation for implementation on a regional/national basis. The Pilot, as planned, will permit a critical evaluation of the monitoring design, individual indicators, data analysis and integration, logistics, QA and information management in preparation for the 1993 Program elements (Heck et al. 1991). The Program, as designed, allows for the orderly establishment and rigorous evaluation of preliminary protocols and for the full utilization of existing data bases and networks.

## 10.3. Tasks and Schedule for the Pilot Project

The principle tasks associated with the Pilot Project are listed in Table 10-1 with a schedule for completion of the tasks. The ARG expects to follow the time schedule closely to assure a successful Pilot and permit a complete development of plans for 1993. An activity chart (Table 10-2) is shown that addresses all aspects of the planned ARG activities for 1992. These are shown without timelines.

## 10.4. Funding and Personnel Resources and Products

These are shown for all activities associated with the ARG in 1992.

Table 10-1. Tasks with schedule for conducting the Pilot Project - NC Pilot Plan (1992-93)

| Tasks | Schedule (1992) |
|---|---|
| 1. Supply procedural manual for enumerator training for Fall survey and sampling | July |
| 2. Use suite of indicators developed in this Plan. | June-Dec |
| 3. Assure that logistic, QA and information management strategies are in place. | Mar-Sept |
| 4. Participate in the NASS Enumerator Training Schools: a) May - procedures for the JES, b) October - procedures for Fall Survey and sampling. | May<br>Oct |
| 5. Obtain all necessary equipment and materials for the pilot. | Apr-Oct |
| 6. Sample 116 NASS segments using NASS personnel, logistics, QA and data management protocol. | June<br>Nov-Dec<br>(NASS Survey Dates) |
| 7. Work with NASS on data management and data analysis. | June-Dec<br>Mar 1993<br>(NASS time periods) |
| 8. Send soil and water samples to contract laboratories for analysis and data return. | Nov-Jan 1993 |
| 9. Compare the two design approaches through sampling of units in the field; cost, variance, biases; determine covariance structure to refine DQOs. | Dec-Mar 1993 |
| 10. Data analysis: provide statistical summaries, compare cumulative distribution functions, explore spatial distribution patterns, and examine statistical properties. | May 1993 |
| 11. Develop data summary to derive initial indices to classify agroecosystems as "healthy" or "unhealthy". | July 1993 |

Table 10-2. 1992 Activity Chart for the ARG.

**1. Primary Focus of the North Carolina Pilot** - The NASS enumerators will be trained to understand the questionnaire and sampling techniques required to obtain data for the NC pilot; a detailed enumerator's manual will be provided. Data will be collected by the enumerators and data quality and logistics will follow NASS guidelines. Soil and water samples will be sent to appropriate laboratories following standard procedures. Data will be managed initially by NASS and then processed by the Agro Resource Group for data analysis and summarization. Design options and indicators will be evaluated and a statistical summary will be prepared. Most of this effort is directed at the 5 basic indicators identified for the Pilot.

a. Prepare Enumerator's Manual
b. Train NASS Enumerators
c. Acquire Materials for Sampling Soil and Water
d. Data/Sample Collection - NASS Enumerators
e. NASS, Other Responsibilities
f. Sample Prep. & Analysis (soils)
g. Sample Preparation and Analysis (water)
h. Management and Analysis of Data
i. Evaluation of Design Options
j. Evaluation of Five Indicators
k. Acquire Equipment/Software for Information Mgmt
l. Evaluate/Update Information Mgmt
m. Evaluate/Update QA/QC
n. Evaluate/Update Logistics
o. Prepare First Annual Statistical Summary

**2. Acquire Found Data and Test Compatibility with Data from the Pilot** - Search other data sets to see what data is present and may be of value for the Agroecosystem. Test ways to determine whether the data is compatible with agro data or can be used in some way to aid in interpretive reports. Data sets of interest include atmospheric, terrestrial and water inputs (SCS, ERS, EPA, etc.).

a. Water Quality
b. Terrestrial and Atmospheric (i.e., weather, ozone, soils, pesticides, etc.)

**3. Evaluation of Research Indicators Tested as Part of the Pilot** - The Agroecosystem Resource Group will continue to test indicators designed to monitor additional components of the agro-ecosystem resource. Work will continue to develop the nematode as an indicator of the biological "health" of the soil system. Additional effort will be put into identifying other specific measurements for water quality. A major effort will continue in the development of habitat indicators that will monitor the vitality of lands adjacent to agricultural fields. The development of habitat indicators will be continued in close cooperation with other Resource Groups and with other agencies, such as USGS and SCS. These indicators will be field tested in NC during the Pilot.

a. Nematodes - Soil Biological Health
b. Habitat - Extent and Quality
c. Water Quality - Irrigation, Farm Ponds, Wells
d. Clover - Ozone Biomonitor

**4. Activities Supportive of the Agroecosystem Resource** - The development of an integrated pilot, in conjunction with the other terrestrial resource groups, will continue with the expectation that the pilot will be undertaken in 1993. Additional work will be done with the Integration and Assessment team in preparation for an example of an integrated assessment. Additional efforts will be made to work with the Regions.

a. Linkages/Integration of Resource Groups
b. Integration and Assessment
c. Regional Interests

**5. Develop 1993 Plans** - The Agroecosystem Resource Group is planning for a Demonstration project in the South East and a Pilot project in Region VII for 1993. Detailed plans, revised questionnaires, revised enumerator manuals, and revisions to all cross-cutting activities are needed for these two field studies.

### *10.4.1. Funding*

The budget by tasks is shown in Table 10-3 and the budget by Location/Category is shown in Table 10-4. Although funding is not at the level requested for an in-depth pilot, it provides sufficient support for a well designed monitoring program to address the issues highlighted in this Plan. It required the use of fewer sampling segments (116) as opposed to our recommended (200) and does not give full funding to several of our ARG members. Direct EMAP support for the Program is shown (Tables 10-3 and 10-4) as well as support coming from other cooperators in the Program.

### *10.4.2. Personnel*

Personnel associated with the ARG are shown in the Organization Structure (Appendix 1). This translates to the number and full time equivalents shown in Table 10-5. Because of the small percentage of time we were able to budget for several of the contact people, we will not receive as much dedicated effort from this group. We expect to have more of their time in 1993. The enumerator's time, covered by NASS, is not shown in the table.

### *10.4.3. Program Products (Outputs)*

In addition to this Pilot Plan we have several other outputs planned in 1992. These are listed below with a title, brief description, due date and comments.

| Title | Brief Description | Due Date | Comments |
|---|---|---|---|
| o Agroecosystem 1992 Pilot Project Plan | Pilot Study Plan | 4/6/92 | Submitted 4/3/92 |
| o Monitoring the Conditions of Agroecosystems | Overview Document | 4/92 | Submitted 3/92 |
| o Comparison of Periodic Survey Designs Employing Multistage Sampling | Comparison of the Hexagon and Rotational Panel Designs | 7/92 | Completed |
| o Sustainable Agriculture | Symp. Proceedings | 6/92 | Completed |
| o Enumerators Manual | Instructions/Training for Enumerators | 10/92 | In Process |
| o Report on Indicator Testing - Soil Nematodes | Analysis of Nematode Data | 10/92 | In Process |

Table 10-3. Program Tasks with Budget for 1992 Pilot

| Task | Primary Activities (Number) 1/ | Funding (Thousands) EMAP | Other 2/ |
|---|---|---|---|
| • Conduct North Carolina Pilot | 1a-g | $ 275 | $ 183 |
| • Manage and analyze data from pilot | 1h,o | 125 | 70 |
| • Evaluate design and sampling options | 1i | 30 | 10 |
| • Evaluate pilot indicators (integration) | 1j | 50 | 61 |
| • Evaluate and update data management protocol | 1k,l | 45 | 10 |
| • Evaluate and update QA/QC protocols/logistics | 1m,n | 20 | 10 |
| • Collect and analyze data from existing data bases - Determine applicability to the Agro database | 2 | 30 | 20 |
| • Evaluate research indicators tested in the Pilot | 3 | 85 | 90 |
| • Activities supportive of the ARG | 4 | 33.6 | 15 |
| • Develop plans for 1993 Regional Demonstration and Pilot | 5 | 50 | 25 |
| Totals | | $ 743.6 | $ 494 |
| Total Pilot Funds | | $ 1,237.6 | |

1/ Corresponds to activity number in Table 10-2
2/ Other funds from EPA laboratories, ARS, NCSU and NASS

Table 10-4. Pilot Budget by Location/Category

| Location | | Funding Thousands EMAP | Other[1] |
|---|---|---|---|
| 1. Locations | | | |
| a) Athens (ERL) | | -[2] | 180 |
| b) Corvallis (ERL) | | 10 | 5 |
| c) Idaho (INEL) | | 10 | 5 |
| d) Las Vegas (ERL) | | 10 | - |
| e) RTP (ERL) | | - | 113 |
| 2. NASS (DC/NC) | | 200 | 20 |
| 3. USDA/ARS/NCSU | | 513.6 | 171 |
| a) Personnel | | 322 | 141 |
| b) Travel | | 29 | 2 |
| c) Supplies/Service | | 38.6 | 3 |
| d) Advisory Com. | | 10 | - |
| e) Equipment | | 34 | - |
| f) Sample Costs | | 30 | - |
| g) Utilities/Space | | 10 | 25 |
| h) Athens | | 40 | - |
| i) Indirect (12.7% waived)[3] | | (65.3) | (+65.3) |
| Totals | | 743.6 | 494 |
| Total for Pilot Funds | $1,237.6 | | |

1/ **Other funds from EPA laboratories, NASS, ARS and NCSU**
2/ **Direct support will come from the USDA budget ($40,000)**
3/ **If the waived indirect costs are included, funds from other sources is $559,300 and direct EMAP funds are $678,300.**

Table 10-5. Personnel/Responsibilities for the Agroecosystem Pilot Project[1/]

| Position | Number | FTEs | Organization |
|---|---|---|---|
| Technical Director | 1 | 1.0 | USDA/ARS |
| Associate Director | 1 | 0.3 | NCSU |
| Professional Staff | | | |
| Biological | 7 | 2.5 | EPA/Contract Labs/ARS |
| Statisticians | 4 | 2.3 | NCSU/NASS/Athens |
| Research Assoc. (Pl. Path/Biomath) | 2 | 2.0 | NCSU |
| Statistician | 2 | 1.0 | NCSU |
| Information Man. | 1 | 1.0 | NCSU |
| QA/Log. | - | 0.2 | NCSU |
| Technicians | 4 | 3.2 | NCSU/Athens/ARS |
| Support Staff | 5 | 1.5 | NCSU |
| Total | 27 | 15.0 | |

1/ The Table does not include the time of the enumerators covered by NASS

## 10.5. Activities, Funding and Personnel Needs for 1993 Demonstration and Pilot Projects

The Agroecosystem Program is planning two primary programs in 1993. The information detailed in this section is based on the level of funding shown in the tables for the planned activities. In the first program, costs are based on a broad coverage Demonstration Project in the S.E. to include eight states (Delaware, Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi). Costs are based on obtaining data from 100 sampling units (segments) per state for a total of 800 segments. This is a broad coverage of the S.E. and permits addressing results on both political and ecological regions of the S.E. The second program is a large Pilot to include the four states (Iowa, Missouri, Kansas and Nebraska) of EPA Region 7. Costs are based on obtaining data from 100 sampling units (segments) per state for a total of 400 segments. This may be sufficient to address results on ecological regions as well as political regions.

The ARG believes it can accomplish the above programs primarily because of the infrastructure that NASS has developed across the country. This permits us to utilize the information developed in the 1992 Pilot across all 12 states with some revision relating to differences in levels of agriculture in several of the states. This will be a major challenge for the ARG but one we can accomplish, if detailed planning can start early and new staff can be added fairly quickly. We are proposing this program to the EMAP Steering Committee in the spring of 1992.

The list of planned activities is detailed in Table 10-6. Budget by activity is shown in Table 10-7 and by category/location in Table 10-8. Personnel needs are developed in Table 10-9.

Detailed planning for 1993 is an iterative process that has already begun in the current document. Revisions of this document will form the basis for both the Demonstration and Pilot Programs planned for 1993.

Table 10-6. 1993 Activity Chart for the ARG.

1. **Primary Activities for the S.E. Regional Demonstration** - The NASS enumerators will be trained within the selected SE states to understand the questionnaire and sampling techniques required to obtain data for the SE Demonstration project. Data will be collected by the enumerators and data quality and logistics will follow NASS guidelines. Soil and water samples will be sent to appropriate laboratories following standard procedures. Data will be managed initially by NASS and then processed by the Agro Resource Group for data analysis and summarization. Design options and indicators will be evaluated and a statistical summary will be prepared.

a. Review/Prepare Enumerator's Manuals
b. Train NASS Enumerators
c. Acquire Materials for Sampling Soil and Water
d. Data Collection - NASS Enumerators
e. NASS, Other Responsibilities
f. Sample Preparation and Analysis (soils)
g. Sample Preparation and Analysis (water)
h. Management and Analysis of Data
i. Evaluation of Selected Indicators
j. Acquire Equipment/Software for Info. Mgmt.
k. Prepare Annual Statistical Summary for Demonstration

2. **Primary Activities for the Region VII Pilot** - The same basic tasks will be required for the Region VII pilot on a single-state basis as was required for the SE Demonstration. This is expected to be a single State effort and will not require multiple training sessions or working with multiple groups of NASS personnel. A separate statistical summary will be prepared for this pilot.

a. Review/Prepare Enumerator's Manuals
b. Train NASS Enumerators
c. Acquire Materials for Sampling Soil and Water
d. Data Collection - NASS Enumerators
e. NASS, Other Responsibilities
f. Sample Preparation and Analysis (soils)
g. Sample Preparation and Analysis (water)
h. Management and Analysis of Data
i. Evaluation of Selected Indicators
j. Prepare Annual Statistical Summary for Pilot

3. **Cross Cutting Activities Supportive of Both the Demonstration and Pilot Projects** - These activities include information management, QA/QC, and logistics. Special effort with go into these activities to assure that all three are compatible with other EMAP activities. A sample integration report will be prepared as part of this overall activity.

a. Evaluate/Update Information Management
b. Evaluate/Update QA/QC
c. Evaluate/Update Logistics
d. Prepare a Sample Integration Report
e. Explore Ways to Integrate "Found" Data into Data from Pilot and Demonstration Projects
f. Continue Staff Development

4. **Evaluation of Research Indicators Tested in Either the Demonstration or Pilot Project** - The Agroecosystem Resource Group will continue to evaluate additional indicators and insert them into the monitoring designs on a limited basis. Work on water quality and habitat will be continued in conjunction with other groups. Preliminary work will be initiated with several socio-economic indicators that have gone through some level of testing. A literature review combined with one or two workshops will be undertaken to establish possible indicators for use with farm animals. These indicators will be considered preliminary but might see limited field testing in 1994.

a. Nematodes - Soil Biological Health
b. Habitat - Extent and Quality
c. Water Quality - Irrigation, Farm Ponds, Wells
d. Clover - Ozone Biomonitor
e. Farm Animals
f. Socio-Economic

4. **Evaluation of Research Indicators Tested in Either the Demonstration or Pilot Project** - *The* Agroecosystem Resource Group will continue to evaluate additional indicators and insert them into the monitoring designs on a limited basis. Work on water quality and habitat will be continued in conjunction with other groups. Preliminary work will be initiated with several socio-economic indicators that have gone through some level of testing. A literature review combined with one or two workshops will be undertaken to establish possible indicators for use with farm animals. These indicators will be considered preliminary but might see limited field testing in 1994.

a. Nematodes - Soil Biological Health
b. Habitat - Extent and Quality
c. Water Quality - Irrigation, Farm Ponds, Wells
d. Clover - Ozone Biomonitor
e. Farm Animals
f. Socio-Economic

5. **Participate in An Integrated Pilot for The Terrestrial Ecosystems** - The Technical Director of Agroecosystem will work closely with the Technical Directors of Arid Lands and Forest Lands in the initiation of an integrated pilot, probably in Colorado. Planning for this pilot was initiated in 1992. A primary purpose of this integrated pilot is to test concepts and the importance of integrated pilots.

6. **Activities Supportive of the Agroecosystem Resource** - We will continue to identify additional areas in which the Agroecosystem can form linkages both within and outside of EMAP. The sample integration report will be completed and other ways to interact with the Integration and Assessment team will be explored. Further exploration of Regional interest and ways to work more effectively with personnel in the regions will be undertaken.

a. Linkages/Resource Group Integration
b. Integration and Assessment
c. Regional Interests

7. **Develop 1994 Plans for the Agroecosystem Resource** - The Agroecosystem Resource Group is planning for three major activities in 1994. This includes a pilot in Region IX, a Demonstration in Region VII, and Implementation in Region IV (the SE). This will require final development of a suite of indicators that will become core indicators for the agroecosystem program. This core group will be used for implementation in Region IV. In the other two regions additional indicators will be tested in addition to the core group. The questionnaires and enumerator manuals will be revised to reflect results from the 1992 and 1993 activities.

Table 10-7. Program Activities with Budget for 1993

| Activity | Funding (Thousands) EMAP |
|---|---|
| 1. Primary Activities for the S.E. Regional Demonstration (8 states) | $1,200 |
| 2. Primary Activities for the Region VII Pilot (4 states) | 600 |
| 3. Cross Cutting Activities Supportive of Both the Demonstration and Pilot Projects | 140 |
| 4. Evaluation of Research Indicators Tested in Either the Demonstration or Pilot Project | 285 |
| 5. Participate in An Integrated Pilot for The Terrestrial Ecosystems | 50 |
| 6. Activities Supportive of the Agroecosystem Resource | 50 |
| 7. Develop 1994 Plans for the Agroecosystem Resource | 75 |
| Total | $2,400 |

Table 10-8. 1993 Budget by Location

| Location | | Funding (Thousands) EMAP |
|---|---|---|
| 1. Locations | | |
| a) Athens (ERL) | | 130 |
| b) Corvallis (ERL) | | 75 |
| c) Idaho (INEL) | | 75 |
| d) Las Vegas (ERL) | | 20 |
| 2. USDA/NASS (DC/States) | | 900 |
| 3. USDA/SCS (DC/States) | | 100 |
| 4. USDA/ARS/NCSU | | 1,100 |
| a) Personnel - current | 300 | |
| b) Personnel - new | 250 | |
| c) Travel | 75 | |
| d) Supplies/Service | 90 | |
| e) Advisory Com. | 25 | |
| f) Equipment | 65 | |
| g) Sample Costs, soil | 130 | |
| h) Utilities/Space | 25 | |
| i) Indirect (12.7%)1/ | 140 | |
| Totals | | $ 2,400 |

1/ **We will ask for waiver of indirect costs; if approved, funds will be used to increase operations budget, which is low.**

Table 10-9. Personnel/Responsibilities for the 1993 Agroecosystem Program

| Position | Current No. | Current FTEs | New No. | New FTEs | Organization |
|---|---|---|---|---|---|
| Technical Director | 1 | 1.0 | | | USDA/ARS |
| Associate Director | 1 | 0.3 | - | 0.2 | NCSU |
| Professional Staff | | | | | |
| Biological | 7 | 2.5 | 3 | 3.0 | EPA/Contract Labs/ARS |
| Statisticians | 4 | 2.3 | 1 | 1.0 | NCSU/NASS |
| Research Assoc. (Pl. Path/Biomath) | 2 | 2.0 | 2 | 2.0 | NCSU |
| Statistician | 2 | 1.0 | 1 | 1.0 | NCSU |
| Information Man. | 1 | 1.0 | | | NCSU |
| QA/Log. | - | 0.2 | 1 | 1.0 | NCSU |
| Technicians | 4 | 2.8 | 4 | 4.0 | NCSU |
| Support Staff | 5 | 1.5 | 1 | 1.5 | NCSU |
| SubTotals | 27 | 14.6 | 13 | 13.7 | |
| Program Totals Staff | 40 | | | | |
| FTEs | 28.3 | | | | |

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**APPENDIX 2**

List of N.C. Counties Sampled in the 1992 Pilot Project

List of counties being sampled for the Agroecosystem 1992 Pilot. Designations following county name indicate sample design which selected the county and the number of segments selected in the county by each design. Hexagon segments chosen by EMAP hexagon 1991 sub-sample; NASS segments chosen using NASS rotational panel design, total segments chosen in each county.

| COUNTY | HEXAGON PLAN | ROTATIONAL PANEL PLAN | TOTAL |
|---|---|---|---|
| ALAMANCE | 1 | 2 | 3 |
| ALEXANDER | | 1 | 1 |
| ALLEGHANY | | | |
| ANSON | | 1 | 1 |
| ASHE | 1 | | 1 |
| AVERY | | | |
| BEAUFORT | 1 | 1 | 2 |
| BERTIE | 1 | | 1 |
| BLADEN | | 1 | 1 |
| BRUNSWICK | | 1 | 1 |
| BUNCOMBE | 1 | 1 | 2 |
| BURKE | | 1 | 1 |
| CABARRUS | | | |
| CALDWELL | 1 | | 1 |
| CAMDEN | | 1 | 1 |
| CARTERET | 2 | | 2 |
| CASWELL | 1 | | 1 |
| CATAWBA | 1 | | 1 |
| CHATHAM | | 1 | 1 |
| CHEROKEE | 1 | | 1 |
| CHOWAN | | 1 | 1 |
| CLAY | | | |
| CLEVELAND | 1 | | 1 |
| COLUMBUS | 1 | | 1 |
| CRAVEN | | 1 | 1 |
| CUMBERLAND | | | |
| CURRITUCK | | | |
| DARE | 1 | 1 | 2 |
| DAVIDSON | | 1 | 1 |
| DAVIE | | 1 | 1 |
| DUPLIN | 1 | 1 | 2 |
| DURHAM | 1 | | 1 |
| EDGECOMBE | 1 | 1 | 2 |
| FORSYTH | 1 | | 1 |
| FRANKLIN | 1 | 1 | 2 |
| GASTON | | 1 | 1 |
| GATES | 1 | | 1 |
| GRAHAM | | | |
| GRANVILLE | 1 | | 1 |
| GREENE | 1 | | 1 |
| GUILFORD | | 3 | 3 |
| HALIFAX | | 1 | 1 |
| HARNETT | 1 | 1 | 2 |
| HAYWOOD | 1 | | 1 |
| HENDERSON | | | |
| HERTFORD | | 1 | 1 |
| HOKE | 1 | | 1 |
| HYDE | 1 | | 1 |

| | | | |
|---|---|---|---|
| IREDELL | | 2 | 2 |
| JACKSON | | 1 | 1 |
| JOHNSTON | 1 | | 1 |
| JONES | 1 | | 1 |
| LEE | | | |
| LENOIR | | 1 | 1 |
| LINCOLN | | | |
| MCDOWELL | | | |
| MACON | 1 | 1 | 2 |
| MADISON | 1 | | 1 |
| MARTIN | | | |
| MECKLENBURG | 1 | | 1 |
| MITCHELL | | | |
| MONTGOMERY | | 1 | 1 |
| MOORE | 1 | 1 | 2 |
| NASH | | 2 | 2 |
| NEW HANOVER | 1 | | 1 |
| NORTHAMPTON | 1 | | 1 |
| ONSLOW | 1 | 1 | 2 |
| ORANGE | | | |
| PAMLICO | | 1 | 1 |
| PASQUOTANK | | | |
| PENDER | | 1 | 1 |
| PERQUIMANS | 1 | | 1 |
| PERSON | | 1 | 1 |
| PITT | 1 | 1 | 2 |
| POLK | | 1 | 1 |
| RANDOLPH | 1 | | 1 |
| RICHMOND | 1 | 1 | 2 |
| ROBESON | 1 | 2 | 3 |
| ROCKINGHAM | 1 | 2 | 3 |
| ROWAN | 1 | 2 | 3 |
| RUTHERFORD | 1 | 1 | 2 |
| SAMPSON | 2 | 1 | 3 |
| SCOTLAND | | 1 | 1 |
| STANLY | 1 | 2 | 3 |
| STOKES | | 1 | 1 |
| SURRY | 1 | | 1 |
| SWAIN | | | |
| TRANSYLVANIA | | | |
| TYRRELL | | 1 | 1 |
| UNION | 1 | 1 | 2 |
| VANCE | | 1 | 1 |
| WAKE | | 1 | 1 |
| WARREN | 1 | | 1 |
| WASHINGTON | | 1 | 1 |
| WATAUGA | | | |
| WAYNE | | 1 | 1 |
| WILKES | 1 | 2 | 3 |
| WILSON | | 1 | 1 |
| YADKIN | | 1 | 1 |
| YANCEY | 1 | 1 | 2 |
| NUMBER OF SEGMENTS: | 51 | 65 | 116 |
| NUMBER OF COUNTIES SAMPLED: | 49 | 55 | 82 |

## APPENDIX 3

Expected Data Summaries from the Agroecosystem 1992 North Carolina Pilot

The information contained in this appendix shows how the ARG expects to summarize some of the data obtained from measurements (indicators) obtained to quantify the assessment endpoints planned for the 1992 Pilot Project. The indicator (measurement) data obtained, the planned summary statistic and the type of summary expected are listed in this appendix for the five primary assessment endpoints planned for the 1992 Pilot.

| *Indicator* | *Summary statistic (SI units)* | *Summary type* |
|---|---|---|
| land area in a given use class | hectares (ha) of each JES land use category | population estimate+std error |
| | ha of each JES crop type/ ha cropland | population estimate+std error |
| | total ha cropland (all JES crops) | population estimate+std error |
| | ha of each Fall survey land use category for 1992 | population estimate+std error |
| yield by crop | kg/hectare for each crop | CDF (ha crop x yield crop) |
| fertilizer use | kg N applied | population estimate+std error |
| | kg P applied | population estimate+std error |
| | ha cropland treated with N | population estimate+std error |
| | ha cropland treated with P | population estimate+std error |
| | ha cropland treated with N or P / ha cropland | CDF (ha cropland x N/ ha)<br>CDF (ha cropland x P/ha) |
| | hectares treated with municipal sludge | population estimate+std error |
| fuel use | liter/hectare | population estimate+std error |
| | ha cropland fuel rate used / ha cropland | CDF (ha cropland x liter fuel/ha) |
| use of a given pesticide class (e.g. phenoxy herbicides) | kg active ingredient (or pesticide class) applied | population estimate+std error |
| (classes to be defined) | hectares cropland treated with active ingredient (or class) | population estimate+std error |
| | hectares cropland treated (with each class) / hectares cropland | population estimate+std error |

| | | |
|---|---|---|
| land area managed with soil conservation methods | hectares managed with each specific conservation method | population estimate+std error |
| (tillage and other erosion control methods- 7 total) | hectares managed by each specific conservation method / ha cropland | population estimate+std error |
| | hectares managed by each specific conservation method / ha cropland managed by one or more conservation methods | population estimate+std error |
| land area managed with non chemical pest controls (3 total) | hectares managed with each specific nonchemical pest control method | population estimate+std error |
| | hectares managed with each specific nonchemical pest control/ ha cropland | population estimate+std error |
| | hectares managed with each specific nonchemical pest control/ ha cropland managed with one or more nonchemical pest control methods | population estimate+std error |
| land area managed with pest control advice (4 total) | hectares managed with each specific pest control advice method | population estimate+std error |
| | hectares managed with each specific pest advice method/ ha cropland | population estimate+std error |
| | hectares managed with each specific pest advice method/ ha cropland managed with one or more pest advice methods | population estimate+std error |
| land area irrigated | hectares cropland irrigated | population estimate+std error |
| | hectares irrigated / ha cropland | population estimate+std error |
| amount of irrigation water used | volume water applied / hectare | CDF (ha cropland x vol water/ha) |
| | volume water applied (in SI unit) | population estimate+std error |
| type of irrigation system | volume water applied by each specific method / volume water applied | population estimate+std error |
| | land area irrigated by each specific method / hectares irrigated cropland | population estimate+std error |

| | | |
|---|---|---|
| source of irrigation water | volume water obtained from each specific irrigation water source / total irrigation water applied | population estimate+std error |
| | hectares cropland irrigated with water from each specific source / ha irrigated cropland | population estimate+std error |
| clay | % by weight | CDF (ha cropland x % clay) |
| organic carbon | % by weight | CDF (ha cropland x % org C) |
| available water capacity | % by volume | CDF (ha cropland x % avail water cap) |
| porosity | % by volume | CDF (ha cropland x % porosity) |
| base saturation | % by weight | CDF (ha cropland x % base satur'n) |
| exchangeable acidity | cmol (+)/kg (centimoles positive charge/kg) | CDF (ha cropland x acidity) |
| % exch. sodium | % by weight | CDF (ha cropland x ESP) |
| pH | pH units | CDF (ha cropland x pH) |
| electrical conductivity | dS/m (decisiemens/meter) | CDF (ha cropland x EC) |
| extractable aluminum | cmol(+)/kg | CDF (ha cropland x Al) |
| cadmium | mg/kg soil | CDF (ha cropland x Cd) |

## APPENDIX 4

METHODS - SOILS ANALYSES

### 1. SAMPLE PREPARATION AND STORAGE

Air-dry samples by spreading the soil out in aluminum pans. Once dry, grind the samples using a hammer mill (2-4 minutes). Homogenize soil thoroughly by shaking sample in an inflated plastic bag for 15-20 seconds. Store soil in excess of volumes necessary for analysis laboratories at room temperature until all data is received and passes DQO standards (Tables 5.2-12 and 5.2-14).

### 2. SOIL MOISTURE

Record empty weight of can with lid. Fill the can with 50 ml fresh soil and record the sample code. Record weight of the can + lid + moist soil. With the lid propped underneath the can, oven-dry the samples at 90 C for 48 hr or until constant dry weights are achieved. Place lid on can immediately after removing the cans from the oven. Allow cans with soil to cool to approximately room temperature before weighing. Record the oven-dry weight of the can + lid + dry soil. Record all weights to the nearest 0.1 g, rounding up if $\geq 0.05$ and down if $< 0.05$g.

**Calculation:**
WET=(AIR-DRY SOIL + CAN) - CAN
DRY=(OVEN-DRY SOIL + CAN) - CAN

$$\% \text{ WATER CONTENT} = \frac{\text{WET - DRY}}{\text{DRY}} * 100$$

**Reference:**
Hillel, D. 1982. Introduction to Soil Physics. Academic Press, Inc., New York. 364 pp.

### 3. SOIL TEXTURE ANALYSIS

Air-dry and grind samples using hammer-mill, then oven-dry soil at 90 C for 48 hr before analysis.

1. Weigh 50 g (*oven dry*) of soil and place in a blender cup and add 100 ml calgon (or equivalent) stock solution.

2. Blend mixture for 20 seconds.

3. Transfer the soil suspension to a sedimentation cylinder and make volume up to 1000 ml with *distilled* water.

4. Shake or stir suspension vigorously. Place cylinder on table and record the time. At the end of 20 seconds, carefully insert the hydrometer and read the hydrometer at the end of 40 seconds from the time stirring ceased. Record the reading on the data sheet.

5. Remove the hydrometer from the suspension. Record the temperature of the suspension and the time at which the readings were taken.

6. Take a reading at the end of 6 hours. Insert hydrometer just before the 6-hr reading is made. Also record temperature.

7. To make up a "control" add 100 ml of calgon (or equivalent) stock solution to a sedimentation cylinder and make volume to 1000 ml by adding distilled water. Take a hydrometer reading each time the 40-sec and 6-hr readings are taken. For each time, subtract the hydrometer reading of the control from the hydrometer reading of the soil suspension.

8. To further correct the hydrometer readings for temperature, for each degree above 68 F, add 0.2 to the reading to get the corrected hydrometer reading. For each degree less than 68 F, subtract 0.2 from the reading.

9. Calculate the percent sand in the sample. The hydrometer is calibrated so that the corrected reading gives the grams of soil material in suspension. The sand settles to the bottom of the cylinder within 40 seconds, therefore, the 40-sec hydrometer reading actually gives the amount of silt and clay in suspension. The weight of sand in the sample is obtained by subtracting the corrected hydrometer reading from the total weight of the sample. The percentage sand is calculated by dividing the weight of sand by the weight of the sample and multiplying by 100.

10. Calculate the percent clay in the sample. At the end of 6 hr, the silt in addition to the sand has settled out of suspension. The corrected hydrometer reading at the end of 6 hr represents the grams of clay in the sample.

11. Calculate the percent of silt in the sample. Find the percent silt by difference. Subtract the sum of percentage of sand and clay from 100 to get the percent silt.

* For organic soils, if < 50 g, record sample weight processed, so a correction can be made in calculation of proportions of soil that are sand, silt, and clay. Hydrometer readings are divided by weight of the sample, as described in steps 9 and 10.

Calgon stock solution:
35.7 g hexametaphosphate $(NaPO_3)_6$
2.1 g $NaCO_3$
1000 ml water

pH should be 8.3-8.5; adjust with $Na_2CO_3$
use within 2 weeks

## 4. ELECTRICAL CONDUCTIVITY (EC)

### Procedure

1. Measure 25 g into a 150 ml beaker, add 50.0 ml deionized water, stir thoroughly with a glass stirring rod and allow suspension to settle for at least 30 minutes or long enough for the solids to settle. For organic soils, use 5.00 g.

2. Pour supernatant into centrifuge tube and centrifuge at high rpm. Transfer the supernatant using a pipet to a container to read EC.

3. Rinse cell with one or more portions of sample. Draw supernatant into the conductivity pipette to slightly above the constricted part of pipette. Avoid drawing liquid into rubber bulb. If this occurs, rinse bulb before continuing with the next sample.

4. Adjust instrument to proper range and record the reading.

5. Rinse cell between samples with deionized water.

**Calculation:**
Electrical conductivity (EC) of the soil extract is calculated as follows:

$$\text{EC in dS/m at 25 C} = \frac{1.4118 \times R_{extract}}{R_{standard}}$$

where the value of 1.4118 is the EC of the standard 0.01 M KCl solution in dS/m at 25 C and $R_{standard}$ and $R_{extract}$ refer to resistance in ohms of the standard (0.01 M KCl) solution and extract, respectively. Report EC values in dS/m.

Alternate method of calculation: After the cell constant ($\Phi$) has been determined, EC of the soil extract can be obtained from the relationship,

$$\text{EC, in dS/m at 25 C} = \frac{\Phi}{R}$$

where $\Phi$ is the determined cell constant and R is the resistance in ohms per cm of the soil extract.

## 5. pH

1. Measure 5 $cm^3$ of soil into 1-oz. cups
2. Add 5 ml deionized water and let sit for 30 minutes
3. Standardize the pH meter:
   a. uncover vent hole on electrode

b. immerse electrode in pH 7 buffer and set thumbwheel to 7.00
c. when button lights and remains on, press button and hold until meter reads 7.000
d. rinse electrode and immerse in pH 4.0 buffer and turn thumbwheel to 4.01--again press the button when lighted and hold until 3 decimal places appear.
e. rinse and leave electrode in pH 7.0 buffer between trays of samples

4. Stir each sample using a glass rod before reading
5. Add 10 ml buffer (pH 7) to each sample
6. Cover each sample with plastic wrap and shake buffers for 10 minutes on slow speed.
7. Read buffered pH values using a pH meter

## 6. EXCHANGEABLE CATIONS IN MEHLICH III EXTRACT

Exchangeable Ca, Mg, K, Na and Al extracted using Mehlich's double-acid method (Sabbe et al. 1974, Tucker and Hight 1990) followed by direct current plasma.

1. 1 $cm^3$ sample of soil is extracted with 10 ml of Mehlich III extractant (0.2 N acetic acid, 0.015 N ammonium fluoride, 0.015 N nitric acid and 0.002 N EDTA) by shaking for 5 minutes at high speed (280 exc/min) and filtering.

2. Dilute sample with LiCl buffer to obtain a final concentration of 3750 ppm Li.

3. Determine cation concentration using a dc plasma spectrophotometer.

Mehlich Extracting Solution
To make 20 liters:

1. 400.2 g ammonium nitrate ($NH_4NO_3$)
2. 80 ml stock solution (see below)
3. 228 ml acetic acid ($CH_3COOH$)
4. 16.5 ml nitric acid ($HNO_3$)*

*Amount varies from one bottle of $HNO_3$ to another, so concentration must be determined prior to use and adjustments made to the protocol.

Adjust pH to 2.5 $\pm$ 0.1. Use nitric acid to lower pH and ammonium hydroxide to raise pH.

Stock solution
To make 1 liter:

1. 138.0 g ammonium fluoride ($NH_4F$)
2. 36.53 g EDTA

Dissolve the $NH_4F$ in deionized water and pour into plastic volumetric flask, then add EDTA.

8700 ppm Li Solution
For 20 liters, use 1062.0 g of LiCl. When using a new lot number, new standards must be diluted.

Mehlich III high standard
To make 1 liter:

Zn 10 ppm
P 60 ppm
Mn 30 ppm
Fe 40 ppm
Cu 4.0 ppm
Mg 240 ppm
Ca 1000 ppm
K 60 ppm
Na 10 ppm
B 10 ppm

**References:**

Evans, C. E., and McGuire, J. A. 1990. Comparison of soil test extractants on Alabama soils. Commun. in Soil Sci. Plant Anal. 21:1037-1050.

Mehlich, A. 1984. Mehlich-3 soil test extractant: A modification of Mehlich-2 extractant. Commun. in Soil Sci. Plant Anal. 15:1409-1416. (original method).

Sabbe, W.E., W.L. Brekard, J.B. Jones, Jr., J.T. Cope, Jr., and J.D. Lancaste. 1974. Procedure used by state soil testing laboratories in the southern region of the United States. Southern Cooperative Series Bulletin 190, Alabama Agriculture Experiment Station, Auburn, Alabama. 23 pp.

Tucker, M.R., and Hight, P.T. 1990. A comparison of the results from three soil testing laboratories using the Mehlich-3 extractant on southeastern Coastal Plain soils. Commun. in Soil Sci. Plant Anal. 21:2197-2208.

## 7. EXCHANGEABLE ACIDITY

Exchangeable acidity is a measure of the amount of exchangeable acidic cations on the soil cation exchange complex.

Use $BaCl_2$ extraction. The extracts are then titrated, and the results expressed as milliequivalents exchangeable acidity per 100 g soil. The extraction and titration procedures are performed with automated equipment using a mechanical extraction. This method is modified from Thomas (1982) and USDA/SCS (1984).

**$BaCl_2$-TEA buffer solution for mineral soils:**

Dissolve 61.07 g $BaCl_2 \cdot 2 H_2O$ and 14.92 g TEA in $CO_2$-free, deionized water and dilute to 1.00

L. Adjust pH to 8.2 with 10% HCl. Protect solution from $CO_2$ contamination by attaching a drying tube containing ascarite to the air intake of the storage vessel.

**$BaCl_2$-TEA buffer solution for organic soils:**

Dissolve 61.07 g $BaCl_2 \cdot 2\ H_2O$ and 29.8 g TEA in $CO_2$-free, deionized water and dilute to 1.00 L. Adjust pH to 8.2 with 10% HCl. Protect solution from $CO_2$ contamination by attaching a drying tube containing ascarite to the air intake of the storage vessel.

**Replacement solution (0.5 *N* with respect to $BaCl_2$):**

Dissolve 61.07 g $BaCl_2 \cdot 2\ H_2O$ with 5 ml of the appropriate $BaCl_2$-TEA buffer solution and dilute to 1.00 L with deionized water.

**Acidity by $BaCl_2$-TEA**
**Mineral soils:**

1. Tightly compress a 1-g ball of filter pulp into the bottom of a syringe barrel with a modified plunger. (To modify the plunger, remove the rubber portion and cut off the plastic protrusion.) Tap the plunger and syringe assembly on a tabletop several times.

2. Weigh 2.00 g air-dry mineral sample into small glass tube and record exact weight. Place sample tube in upper disc of extractor and connect to inverted extraction syringe, with the syringe plunger inserted in the slot of the stationary disc of the extractor. Attach pinch clamp to delivery tube of syringe barrel. Add 10.00 ml $BaCl_2$-TEA *buffer* solution for mineral soils to the sample. Stir the sample mixture with a glass stirring rod for 10 seconds. Leave stirring rod in syringe. Allow sample to stand for 30 minutes.

3. Set extractor for a 30-minute rate and extract until 0.5 to 10.0 cm of solution remains above each sample. If necessary, turn off extractor to prevent soil from becoming dry.

4. Add a second 10.00-ml aliquot of $BaCl_2$-TEA *buffer* solution and continue extracting until nearly all solution has been pulled through sample. Add *replacement* solution from pipettor in two 20-ml aliquots, passing the first aliquot through the sample before adding the next. Total time for replacement should be approximately 30 minutes. Quantitatively transfer extract to an Erlenmeyer flask. Record the total volume of buffer plus replacement solutions.

   NOTE: Deionized water may be used at this point to aid in the quantitative transfer. The final volume of deionized water should be 100 ml--see Step 5.

5. Titration--Add 100 ml deionized water to extract in Erlenmeyer flask. Use an automatic titrator to titrate with 0.050 *N* HCl to a 4.60 pH endpoint. Record volume

and normality of titrant. If the volume of titrant of any sample is less than 5% of that measured for the blank, resolve the problem before further analysis.

**Organic soils**

1. Tightly compress a 1-g ball of filter pulp into the bottom of a syringe barrel with a modified plunger. (To modify the plunger, remove the rubber portion and cut off the plastic protrusion.) Tap the plunger and syringe assembly on a tabletop several times.

2. Weigh 2.00 g air-dry organic sample into small glass tube and record exact weight. Add 5.0 ml $BaCl_2$-TEA *buffer* solution for organic soils to the sample, cap, and shake the tube and contents for 1 hour on a reciprocating shaker. Place sample tube in upper disc of extractor and connect to inverted extraction syringe, with the syringe plunger inserted in the slot of the stationary disc of the extractor. Attach pinch clamp to delivery tube of syringe barrel. Quantitatively transfer contents of small glass tube to sample tube with 5.00 ml *buffer* solution.

   NOTE 1: Five to 10 ml of buffer solution may be used to transfer soil to syringe--see Step 4.

   NOTE 2: Some organic soils have very high acidity, which may require reducing the amount of soil to 1.00 g to stay in the mid-range of the titration procedure.

3. Set extractor for a 30-minute rate and extract until 0.5 to 10.0 cm of solution remains above each sample. If necessary, turn off extractor to prevent soil from becoming dry.

4. Add a second 10.00-ml aliquot of $BaCl_2$-TEA *buffer* solution and continue extracting until nearly all solution has been pulled through sample. Add *replacement* solution from pipettor in two 20-ml aliquots, passing the first aliquot through the sample before adding the next. Total time for replacement should be approximately 30 minutes. Quantitatively transfer extract to an Erlenmeyer flask. Record the total volume of buffer plus replacement solutions.

   NOTE 1: If 10-ml was used in Step 2, then 5 ml must be used here. Total buffer used must equal 20.00 ml. A second extraction is essential.

   NOTE 2: Deionized water may be used at this point to aid in the quantitative transfer. The final volume of deionized water should be 100 ml--see Step 5.

5. Titration--Add 100 ml deionized water to extract in Erlenmeyer flask. Use an automatic titrator to titrate with 0.100 N HCl to a 4.60 pH endpoint. Record volume and normality of titrant. If the volume of titrant of any sample is less than 5 percent of that measured for the blank, resolve the problem before further analysis.

**Calculation:**

$$\text{Acidity in } BaCl_2 \text{ (meq/100g)} = \left[ \frac{\left( \begin{matrix}\text{mean blank} \\ \text{volume (ml)}\end{matrix} - \begin{matrix}\text{Titrant} \\ \text{volume (ml)}\end{matrix} \right) * \begin{matrix}\text{Normality} \\ \text{of HCl}\end{matrix}}{\text{sample wt.} * \left[ 1 - \frac{\text{MOIST}}{100 + \text{MOIST}} \right]} \right] * 100$$

MOIST = % water content of soil sample.

**References:**

Thomas, G.W. 1982. Exchangeable cations. Pages 159-165. In: Page, A.L., R.H. Miller, and D.R. Keeney (eds.) Methods of soil analysis. American Society of Agronomy, Madison, WI.

U.S. Department of Agriculture/Soil Conservation Service. 1984. Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples. Soil Survey Investigations Report No. 1. U.S. Government Printing Office, Washington, D.C.

## 8. CATION EXCHANGE CAPACITY

Calculated. The concentrations (meq/100g) of the exchangeable cations (K, Ca, Mg, Na) plus exchangeable acidity should approximate the cation exchange capacity (CEC).

## 9. BASE SATURATION

Calculated. Base saturation is given as the total amount of exchangeable base cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, and $Na^+$) divided by the CEC.

## 10. MINERALIZABLE NITROGEN

**Procedure**

1. Place 12.5 $\pm$ 1 ml of water in a 16 mm x 150 mm test tube, and add 5.00 g of air-dried, sieved (< 2mm) soil. For organic soils use 1.25 g.

2. Stopper the tube, shake, and place it in a constant-temperature cabinet at 30 C for 2 weeks.

3. At the end of this period, shake the tube for about 15 sec and transfer the contents to a 150-ml distillation flask designed for use with the steam distillation apparatus described by Bremner (1965).

4. Complete the transfer by rinsing the test tube three times with 3-5 ml of 4 N KCl using a total of 12.5 $\pm$ 1 ml of this reagent.

5. Add 0.25 $\pm$ 0.05 g of heavy, carbonate-free MgO.

**Analysis by distillation and titration (Bremner)**

Determine the amount of ammonium-nitrogen in the incubated soil sample by collection and titration of the ammonia-nitrogen liberated by steam distillation of the soil-potassium chloride mixture for 4 min using the distillation apparatus and technique described by Bremner (1965).

Note: In this technique, the rate of distillation is approximately 7.5 ml per min, and the ammonia liberated by distillation is collected in a 50-ml Erlenmeyer flask containing 5 ml of boric acid-indicator solution and is determined by titration of the distillate with standardized 0.100 N HCl.

**Analysis by automated distillation-titration**

1. Remove sample tubes and quantitatively transfer each sample to a 250-ml digestion tube. To remove the sample, blow the filter pulp and soil out of the syringe by using a gently flow of compressed air. Wash with a minimum amount of deionized water. Use a rubber policeman to complete the transfer.

2. Add 6-7 g NaCl to the digestion tube, spray silicone antifoam solution into the digestion tube and connect it to the Kjeltec Auto 1030 or similar Analyzer.

3. Follow instructions in manual regarding safety and operation of the analyzer and titrate to a pH 4.60 endpoint.

4. Read ml titration and record with the normality of titrant: $NH_4OAc$.

**Calculation**

$$\text{Min. N (meq/100g)} = \frac{\text{Titrant volume x normality of } H_2SO_4}{\text{sample wt. x (1-(MOIST/(100+ MOIST)))}} \times 100$$

MOIST = % water content of soil sample

**References**

Waring, S. A. and J. M. Bremner. 1964. Ammonium production in soil under waterlogged conditions as an index of nitrogen availability. Nature 201:951-952.

Bremner, J.M. 1965. Nitrogen availability indexes. In: C.A. Black et al. (ed). Methods of Soil Analysis, Part 2. Agronomy 9:1324-1345. Am. Soc. of Agron., Madison, WI.

Keeney, D. R. 1982. Nitrogen--Available Indices. Pages 711-733 in: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. Agronomy Monograph No. 9 (2nd ed.). ASA-SSSA, Madison, WI.

## 11. EXTRACTABLE PHOSPHOROUS USING BRAY II

1. 1 $cm^3$ of soil is extracted with 10 ml of $P_2$ extracting solution (0.03 N $NH_4F$ in 0.1 N HCl) by shaking for five minutes at high speed (280 exc/min).

2. The extract is then filtered with #2 filter papers and phosphorus quantified using a direct current plasma spectrophotometer.

Regression equation to compare Mehlich III and Bray II:
Mehlich-III-P (ppm) = -13 + 0.79 Bray-II-P (ppm), $r=0.95^{**}$, n=59 (Tran et al. 1990)
**: $P<0.01$

**Reference:**

Tran, T. S., Giroux, M., Guilbeault, J. and Audesse, P. 1990. Evaluation of Mehlich-III extractant to estimate the available P in Quebec soils. Commun. in Soil Sci. Plant Anal. 21:1-28.

## 12. ORGANIC CARBON

1. 1 $cm^3$ of soil is used (assumed weight of 1.2 g of soil per 1 $cm^3$).

2. Ash samples at 360 C for 2 hours.

3. Calculate the percent weight loss with ashing.

4. Percent weight loss by combustion can be transformed to the percent organic matter determined by the Walkley-Black procedure a regression equation (Storer 1984, 1992).

   % OM (Walkley-Black) = 68.4 (weight loss) - 0.5
   $r = 0.90$

**Reference:**

Storer, D. 1984. A simple high sample volume ashing procedure for determination of soil organic matter. Commun. in Soil Sci. Plant Anal. 15:759-772.

Storer, D. 1992. An improved high sample volume ashing procedure for determination of soil organic matter. Commun. in Soil Sci. Plant Anal. (in preparation)

## 13. MERCURY

The cold-vapor atomic absorption method, is based on the absorption of radiation at the 253.7-nm wavelength by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration. The typical detection limit for this method is 0.0002 mg/L.

**Reagents**

1. ASTM Type II water: Water should be monitored for impurities.

2. Aqua regia: Prepare immediately before use by carefully adding three volume of concentrated HCl to one volume of concentrated $HNO_3$.

3. Sulfuric acid, 0.5 N: Dilute 14.0 mL of concentrated sulfuric acid to 1 liter.

4. Stannous sulfate: Add 25 g stannous sulfate to 250 mL of 0.5 N sulfuric acid. This mixture is a suspension and should be stirred continuously during use. A 10% solution of stannous chloride can be substituted for stannous sulfate.

5. Sodium chloride-hydroxylamine sulfate solution: Dissolve 12 g of sodium chloride and 12 g of hydroxylamine sulfate in Type II water and dilute to 100 mL. Hydroxylamine hydrochloride may be used in place of hydroxylamine sulfate.

6. Potassium permanganate, mercury-free, 5% solution (W/V): Dissolve 5 g of potassium permanganate in 100 mL of Type II water.

7. Mercury stock solution: Dissolve 0.1354 g of mercuric chloride in 75 mL of Type II water. Add 10 mL of concentrated nitric acid and adjust the volume of 100.0 mL (1.0 mL = 1.0 mg Hg).

8. Mercury working standard: Make successive dilutions of the stock mercury solution to obtain a working standard containing 0.1 µg/mL. This working standard and the dilution of the stock mercury solutions should be prepared fresh daily. Acidity of the working standard should be maintained at 0.15% nitric acid. This should be added to the flask, as needed, before adding the aliquot.

**Procedure**

1. Sample preparation: Weigh triplicate 0.2-g portions of untreated sample and place in the bottom of a BOD bottle. Add 5 mL of Type II water and 5 mL of aqua regia. Heat 2 min in a water bath at 95°C. Cool; then add 50 mL Type II water and 15 mL potassium permanganate solution to each sample bottle. Mix thoroughly and place in the water bath for 30 min at 95°C. Cool and add 6 mL of sodium chloride-hydroxylamine sulfate to reduce the excess permanganate.
   CAUTION: Do this addition under a hood, as $Cl_2$ could be evolved. Add 55 mL of Type II water. Treating each bottle individually, add 5 mL of stannous sulfate and immediately attach the bottle to the aeration apparatus. Continue as described under step 7.4.

2. An alternative digestion procedure employing an autoclave may also be used. In this method, 5 mL of concentrated $H_2SO_4$ and 2 mL of concentrated $HNO_3$ are added to the 0.2 g of sample. Add 5 mL of saturated $KMnO_4$ solution and cover the bottle with a

piece of aluminum foil. The samples are autoclaved at 121°C and 15 lb for 15 min. Cool, dilute to a volume of 100 mL with Type II water, and add 6 mL of sodium chloride-hydroxylamine sulfate solution to reduce the excess permanganate. Purge the dead air space and continue as described under step 7.4.

3. Standard preparation: Transfer 0.0-, 0.5-, 1.0-, 2.0-, 5.0-, and 10-mL aliquots of the mercury working standard, containing 0-1.0 µg of mercury, to a series of 300-mL BOD bottles. Add enough Type II water to each bottle to make a total volume of 10 mL. Add 5 mL of aqua regia and heat 2 min in a water bath at 95°C. Allow the sample to cool; add 50 mL Type II water and 1 mL of $KMnO_4$ solution to each bottle and return to the water bath for 30 min. Cool and add 6 mL of sodium chloride-hydroxylamine sulfate solution to reduce the excess permanganate. Add 50 mL of Type II water. Treating each bottle individually, add 5 mL of stannous sulfate solution, immediately attach the bottle to the aeration apparatus, and continue as described in step 7.4.

4. Analysis: At this point, the sample is allowed to stand quietly without manual agitation. The circulating pump, which has previously been adjusted to a rate of 1 L/min, is allowed to run continuously. The absorbance, as exhibited either on the spectrophotometer or the recorder, will increase and reach maximum within 30 sec. as soon as the recorder pen levels off (approximately 1 min), open the bypass valve and continue the aeration until the absorbance returns to its minimum value. Close the bypass valve, remove the fritted tubing from the BOD bottle, and continue the aeration.

5. Construct a calibration curve by plotting the absorbances of standards versus micrograms of mercury. Determine the peak height of the unknown from the chart and read the mercury value from the standard curve.

6. Analyze all EP extracts, all samples analyzed as part of a delisting petition, and all samples that suffer from matrix interferences by the method of standard additions (see Method 7000, Section 8.7).

7. Duplicates, spiked samples, and check standards should be routinely analyzed.

8. Calculate metal concentrations: (1) by the method of standard additions, (2) from a calibration curve, or (3) directly from the instrument's concentration read-out. All dilution or concentration factors must be taken into account. Concentrations reported for multiphased or wet samples must be appropriately qualified (e.g., 5 µg/g dry weight).

**References:**

Methods for Chemical Analysis of Water and Wastes, EPA-600/4-82-055, December 1982, Method 245.5.

Gaskill, A., Compilation and Evaluation of RCRA Method Performance Data, Work Assignment No. 2, EPA Contract No. 68-01-7075, September 1986.

## 14. SOIL MOISTURE DETERMINATIONS WITH PRESSURE PLATE

Pack soil to a given bulk density in the rings used with the pressure plate apparatus.

Nitrogen in pressurized tanks are used to achieve pressure within the pressure plate apparatus.

Apply pressure (tension) to the pressure plate to achieve equilibrated matric potentials of -5, -10, -33, and -1500 kPa (equal -0.050, -0.10, -0.3, and -15 bars, respectively).

Soil water content must be determined at each soil matric potential. Soil water content at soil saturation must be known for proper calibration of water content of unsaturated soils.

Express the pore volume available at each matric potential as a function of soil water content (% soil volume). A water release curve can be drawn by plotting the soil water content as the y-axis and the soil matric potential as the x-axis.

NOTE: Soil moisture retention in a low-suction range (0-100 kPa) is strongly influenced by soil structure and pore-size distribution. Hence, measurements made on disturbed samples cannot be expected to represent field conditions (Hillel 1982).

**Reference:**

Hillel, D. 1982. Introduction to Soil Physics. Academic Press, Inc., New York. 364 pp.

# APPENDIX 5

## NASS SURVEY QUESTIONNAIRES

The first part of this Appendix contains the complete NASS questionnaire that will be administered in November 1992 for the Agroecosystem component of EMAP. The survey questionnaire is in draft form at this time and is not for distribution, as NASS had not yet given approval for distribution.

The second part of this Appendix is the subset of the June Enumerative Survey which will be used on the segments selected by the Hexagon Design. It contains the eight extra questions which the ARG, with the concurrence of NASS, has added to the regular JES specifically for the Agroecosystem Program. Segments selected by the Rotational Panel Design will recieve the full JES, including the eight extra questions (7a, 10, 51, 51a, 51b, 52, 52a, 52b).

NATIONAL AGRICULTURAL STATISTICS SERVICE

U.S. Department of Agriculture

Washington, D.C. 20250

Form Approved
O M B Number 0535-0218
Expiration Date 09/30/93
PROJECT CODE 920

# 1992
# EMAP PILOT SURVEY

North Carolina

| State | Stratum | Segment | Tract | Subtr. |
|---|---|---|---|---|
| ___ | _____ | 00000 _____ | ___ | ___ |

| CONTACT RECORD | | |
|---|---|---|
| DATE | TIME | NOTES |
| | | |
| | | |
| | | |
| | | |
| | | |

| COMPLETION CODE | |
|---|---|
| 3 - COMPLETED<br>8 - REFUSAL<br>9 - INACCESSABLE | 001 |

**INTRODUCTION**
[*Introduce yourself and ask for the operator. Rephrase in your own words.*]

The National Agricultural Statistics Service in cooperation with North Carolina State University is conducting a survey of farm chemical use and cropping practices as they relate to the environment. Information from this and other surveys will be used to monitor the agricultural and environmental conditions within North Carolina. This information will be used only for environmental analysis. Authority for collection of this data is Title 7, Section 2204 of the U.S. Code. Response to this survey is confidential and voluntary.

We encourage you to use your farm records during the interview.

BEGINNING TIME [*MILITARY*] ..... 063 _____

## A FIELD IDENTIFICATION A

[*Show aerial photograph to respondent and identify sample field.*]

1. Did you make any of the day-to-day farming decisions for this field in 1992?
   **YES** - [*Enter* ***Code 1***]..... CODE 064
   [*If* **NO**, *conclude the interview, and ask for the respondent's assistance in locating the correct operator.*]

2. How many acres are in this field? (*Include woods, waste, etc.*)..... ACRES 069 .__

3. How many acres in this field are considered cropland?..... ACRES 060 .__

4. Do you (*Does this operation*) own this field or rent it?
   [*Enter* ***code 1*** *for* ***OWNED***;
   *enter* ***code 2*** *for* ***RENTED, LEASED*** *or* ***USED RENT FREE.***]..... CODE 073

## CROP AND LAND USE CODES

| | |
|---|---|
| 1 | ALFALFA, HAY |
| 53 | APPLES |
| 102 | ASPARAGUS |
| 2 | BARLEY |
| | **BEANS,** |
| 3 | DRY |
| 131 | SNAP, ALL |
| 115 | GREEN LIMA |
| 103 | BEETS |
| 104 | BROCCOLI |
| 84 | BUCKWHEAT |
| 106 | CABBAGE, ALL |
| 4 | CANTALOUPS |
| 107 | CARROTS |
| 108 | CAULIFLOWER |
| 58 | CHERRIES, ALL |
| 87 | CHRISTMAS TREES |
| 310 | CLOVER |
| | **CORN,** |
| 6 | FIELD |
| 5 | SILAGE |
| 110 | SWEET |
| 111 | CUCUMBER, ALL |

| | |
|---|---|
| 112 | EGGPLANT |
| 10 | FORAGE, ALL |
| 63 | GRAPES, ALL |
| 311 | GRASSES OTHER THAN CLOVER |
| 116 | GREENS |
| 11 | HAY, ALL OTHER |
| 117 | LETTUCE, ALL |
| 93 | MUSHROOMS |
| 95 | NURSERY & FLORAL CROPS |

**OTHER CROPS** (*Specify*)

_____

_____

_____

_____

_____

| | |
|---|---|
| 15 | OATS |
| 118 | OKRA |
| | **ONIONS,** |
| 120 | DRY |
| 119 | GREEN |
| | **ORIENTAL VEG.,** |
| 148 | ALL |
| 121 | PARSLEY |
| 68 | PEACHES, ALL |
| 16 | PEANUTS |
| 69 | PEARS, ALL |
| | **PEAS,** |
| 122 | GREEN |
| 123 | OTHER |
| | **PEPPERS,** |
| 126 | BELL |
| 127 | ALL OTHER |
| 71 | PLUMS |
| 19 | POPCORN |
| 20 | POTATOES, IRISH |
| 128 | PUMPKINS |
| 129 | RADISHES |
| 140 | RASPBERRIES |
| 22 | RYE |

| | |
|---|---|
| | **SORGHUM,** |
| 25 | GRAIN |
| 24 | SILAGE |
| 26 | SOYBEANS |
| 132 | SPINACH |
| 133 | SQUASH |
| 74 | STRAWBERRIES |
| 30 | SUNFLOWERS |
| 31 | SWEET POTATOES |
| 32 | TOBACCO |
| 134 | TOMATOES, ALL |
| 145 | TURNIPS |
| 33 | WATERMELONS |
| 34 | WHEAT, ALL |

**OTHER LAND USES**

| | |
|---|---|
| 301 | PASTURE |
| 302 | C.R.P. |
| 303 | SET ASIDE |
| 304 | IDLE CROPLAND |
| 901 | FALLOW |
| 305 | WOODLAND |
| 313 | WETLAND |
| 314 | RANGELAND |
| 306 | NON-AG OTHER (*Specify*) |

_____

_____

_____

# B LAND USE and TILLAGE HISTORY B

1. Now I'd like to obtain the land use history for this field for the past three years. Please report all crops grown, including cover crops. Let's start with the 1992 crop year. What was the field used for in 1992?
*[Use a separate line for each use of the field each year.]*

| 1<br>CROP YEAR | 2<br>CROP or LAND USE<br>*[Write in]* | 3<br>CODE | 4<br>How many acres were planted?<br>*[If column 2 use is not a crop, record acres of reported land use.]* | 5<br>How many acres were harvested? | 6<br>What was the average yield per acre? | 7<br>*[Record reported unit]* | 8<br>How much did the *[unit recorded in column 7] weigh?*<br>*[If reported unit is pounds enter 1]* | 9<br>When was this crop planted?<br>MMDDYY | 10<br>When was harvest completed?<br>MMDDYY |
|---|---|---|---|---|---|---|---|---|---|
| 1992 | | 101 | 141 . __ | 161 . __ | 181 | | 201 | 221 | 236 |
| 1992 | | 102 | 142 . __ | 162 . __ | 182 | | 202 | 222 | 237 |
| 1992 | | 103 | 143 . __ | 163 . __ | 183 | | 203 | 223 | 238 |
| 1992 | | 104 | 144 . __ | 164 . __ | 184 | | 204 | 224 | 239 |
| 1992 | | 105 | 145 . __ | 165 . __ | 185 | | 205 | 225 | 240 |
| 1991 | | 106 | 146 . __ | 166 . __ | 186 | | 206 | | |
| 1991 | | 107 | 147 . __ | 167 . __ | 187 | | 207 | | |
| 1991 | | 108 | 148 . __ | 168 . __ | 188 | | 208 | | |
| 1991 | | 109 | 149 . __ | 169 . __ | 189 | | 209 | | |
| 1991 | | 110 | 150 . __ | 170 . __ | 190 | | 210 | | |
| 1990 | | 111 | 151 . __ | 171 . __ | | | | | |
| 1990 | | 112 | 152 . __ | 172 . __ | | | | | |
| 1990 | | 113 | 153 . __ | 173 . __ | | | | | |
| 1990 | | 114 | 154 . __ | 174 . __ | | | | | |
| 1990 | | 115 | 155 . __ | 175 . __ | | | | | |

a. *[If soybeans were reported in 1992]*
*What variety of soybeans were grown? [Enter Code]* ..... CODE 241

## B land use and tillage history---continued B

For the remainder of this interview we will be asking for information for only the 1992 crop year.

2. [*Ask only if crops, idle cropland and/or government program land was reported in item 1.*]
Now I'd like to obtain the tillage history for this field for the 1992 crop year.

| 1<br>CROP OR LAND USE<br>[*Write in*] | 2<br>CROP CODE | 3<br>What type of tillage was used on this field in 1992?<br>1 NONE<br>2 NO-TILL<br>3 RIDGE-TILL<br>4 MULCH-TILL (OR OTHER CONSERVATION TILLAGE)<br>5 CONVENTIONAL (MOLDBOARD PLOW)<br>6 OTHER CONVENTIONAL | 4<br>What erosion control methods were used on this field?<br>1 NONE<br>2 TERRACING<br>3 CONTOUR CROPPING OR PLOWING<br>4 STRIP CROPPING<br>5 GRASSED WATERWAYS<br>6 OTHER (SPECIFY) | | |
|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd |
| | 245 | 251 | 261 | 271 | 281 |
| | 246 | 252 | 262 | 272 | 282 |
| | 247 | 253 | 263 | 273 | 283 |

3. Has the Soil Conservation Service evaluated this field?

CODE

☐ **YES** - [*Enter Code 1 and continue.*] ..... 265

☐ **NO** - [*Skip to Section C, page 5.*]

a. Has the Soil Conservation Service classified this field as "Highly Erodible"?

CODE

☐ **YES** - [*Enter Code 1 and continue.*] ..... 266

☐ **NO** - [*Skip to Section C, page 5.*]

## C FERTILIZER USAGE HISTORY C

### SOIL TESTING

1. Were any soil tests made for this field:

   a. in 1992? ☐ YES - [*Enter* Code1] ..... 1992 300
   ☐ NO

   b. in 1991? ☐ YES - [*Enter* Code 1] ..... 1991 301
   ☐ NO

### SLUDGE USAGE

2. Has municipal sludge been applied to this field at any time during the last five years?
   ☐ YES - [*Enter* Code 1] ..... CODE 309
   ☐ NO

### MANURE USAGE

3. Was manure applied to this field at any time during the 1992 crop year? (*Exclude sludge.*)

   ☐ YES - [*Enter* Code 1 *and continue.*] ..... CODE 310

   ☐ NO - [*Skip to item 5.*]

4. Now I need to get some specific information about the manure applications for all crops grown in this field this year.

| 1<br>CROP OR LAND USE<br>[*Write In*] | 2<br>CROP CODE | 3<br>What kind of manure was applied during 1992 crop year?<br>[ENTER CODE] | 4<br>How much was applied per acre? | 5<br>UNIT CODE<br>LBS = 1<br>CWT = 2<br>TON = 3 |
|---|---|---|---|---|
| | 391 | 311 | 321 | 331 |
| | 392 | 312 | 322 | 332 |
| | 393 | 313 | 323 | 333 |

| MANURE TYPES | |
|---|---|
| 1 | CATTLE |
| 2 | HOG |
| 3 | SHEEP |
| 4 | GOATS |
| 5 | CHICKENS |
| 6 | TURKEYS |
| 7 | HORSES |
| 8 | OTHER (*Specify*) |

## C fertilizer usage history---continued C

5. Was any Lime or Gypsum used on this field for any crop in 1992?

☐ **YES** - [*Enter* **Code 1** *and Complete table.*] ..... 1200

☐ **NO** - [*Go to item 6 on Page 7.*]

| 1<br>CROP OR LAND USE<br>[*Write In*] | 2<br>CROP CODE | 3<br>MATERIAL | 4<br>How many tons were applied per acre? | 5<br>How many total acres were treated?<br>ACRES |
|---|---|---|---|---|
| | 395 | LIME | 370 .__ | 376 .__ |
| | 396 | GYPSUM | 371 .__ | 377 .__ |
| | 397 | LIME | 372 .__ | 378 .__ |
| | 398 | GYPSUM | 373 .__ | 379 .__ |

***Notes and Calculations:***

# C fertilizer usage history---continued C

## COMMERCIAL FERTILIZER USAGE

6. Were commercial fertilizers applied to this field at any time during the 1992 crop year?

CODE 320

☐ YES - [*Enter* **Code 1** *and continue.*] .....

☐ NO - [*Skip to Section D, page 8.*]

| T-TYPE | TABLE |
|---|---|
| 2 | 001 |

**MATERIAL UNIT CODES**

| | |
|---|---|
| 1 | Pounds of materials |
| 12 | Gallons of materials |
| 15 | Ounces |
| 19 | Actual nutrients (*pounds*) |

7. For each fertilizer applied to this field in the past year, I need some information on the analysis applied and the amount applied. What was the first fertilizer you applied ? (*Include sidedressing.*) [*Complete table.*]

| LINE | 1 CROP OR LAND USE [*Write In*] | 2 CROP CODE | 3 MATERIAL USED [*Enter percent analysis or actual pounds of plant nutrients applied per acre.*] N | P | K | 4 How much was applied per acre per application? [Leave this column blank if actual nutrients were reported | 5 [*Enter Unit Code*] | 6 How many acres were treated? |
|---|---|---|---|---|---|---|---|---|
| 01 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 02 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 03 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 04 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 05 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 06 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 07 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 08 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 09 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 10 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 11 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 12 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 13 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 14 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |
| 15 | | 080 | 082 | 083 | 084 | 085 | 086 | 087 . __ |

| T-TYPE | TABLE | LINE |
|---|---|---|
| 0 | 000 | 00 |

| OFFICE USE |
|---|
| 007 |

# D PEST MANAGEMENT D

1. Were any pesticides (*such as herbicides, insecticides, fungicides, nematicides, defoliants or growth regulators*) applied to this field in 1992?

CODE

☐ **YES** - [*Enter* **Code 1** *and complete table.*] ..... 089

☐ **NO** - [*Go to item 2, page 9.*]

**APPLICATION METHODS**

| | | | |
|---|---|---|---|
| 1 | Broadcast (Ground) | 5 | Band In/Over Row |
| 2 | Broadcast (Air) | 6 | Directed Spray |
| 3 | In Furrow | 7 | Chiseled/Knifed -in |
| 4 | Irrigation Water | 8 | Foliar Application |
| | 9 Spot Treatment | | |

| T-TYPE | TABLE |
|---|---|
| 3 | 002 |

| LINE | 1 Crop or Land Use [*Write In*] | 2 Crop Code | 3 What pesticides were applied? [*Enter Code*] | 4 How many acres were treated? ACRES | 5 How much was applied per acre (*per application*)? RATE | 6 [*Enter Unit Code*] 1 Pound 12 Gallon 13 Quart 14 Pint 15 Ounce | 7 How was it applied? [*Enter Code*] | 8 Number of times applied? |
|---|---|---|---|---|---|---|---|---|
| 01 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 02 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 03 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 04 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 05 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 06 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 07 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 08 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 09 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 10 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 11 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 12 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 13 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 14 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |
| 15 | | 090 | 092 | 093 .__ | 094 .__ | 095 | 096 | 099 |

[***ENUMERATOR NOTE:*** *If any chemical is reported for which no code is on the listing sheet, complete the appropriate line in the table above (leaving out the unknown product code), and record the name and a description of the chemical below.*]

| LINE NUMBER | CHEMICAL NAME & FORMULATION | LIQUID OR DRY PRODUCT | EPA NUMBER |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

## D pest management--continued D

Now I'll be asking about pest management and services for crops grown in this field. Consider the management and services you used for insect management, weed control, etc.

| T-TYPE | TABLE | LINE |
|---|---|---|
| 0 | 000 | 00 |

2. Considering the crops grown in this field, have you consulted with any of the following for pest management in 1992--

| CROP OR LAND USE [Enter Code] | | |
|---|---|---|
| 574 | 540 | 545 |
| 575 | 541 | 546 |
| 576 | 542 | 547 |
| 577 | 543 | 548 |
| 578 | 544 | 549 |

a. Hired Staff? (*Include only those trained in pest management, entomology, etc.*)
☐ YES - [*Enter* Code 1] .....
☐ NO

b. Local extension service/university/state/federal?
YES - [*Enter* Code 1] .....
NO

c. Chemical dealer, supplier or store?
☐ YES - [*Enter* Code 1] .....
☐ NO

d. Professional scouts?
(*Exclude scouting provided by a chemical supplier.*)
☐ YES - [*Enter* Code 1] .....
☐ NO

3. Now I need to ask you about some specific pest management practices you may have used for the crops harvested from this field this year.

a. Was the specific variety of the crop(s) you planted this year chosen for pest or disease resistance? 587
☐ YES - [*Enter* Code 1] .....
☐ NO

b. Did you use pheromones or insect traps for monitoring and/or controlling pests? 589
☐ YES - [*Enter* Code 1] .....
☐ NO

c. How about crop rotations? 593
☐ YES - [*Enter* Code 1] .....
☐ NO

| OFFICE USE |
|---|
| 009 |

# E FIELD OPERATIONS E

Now I'd like to find out how many gallons of fuel were used in this field for the 1992 crops. To do this we'll collect information about each piece of equipment and machinery used on the field and the amount of fuel it used. Let's begin with the first operation performed after the 1991 crop harvest.

| LINE | 1 What crop was this for? | 2 Crop Code | 3 What type of operation was done? [Write In] | 4 Machine Code | 5 What was the PTO horsepower of the tractor used? [Code] | 6 What type of fuel did this tractor use? 1 DIESEL 2 GASOLINE 3 LP GAS 4 OTHER | 7 How many total gals. of fuel *or* How many gals. of fuel / acre were used? Total Gals | or Gals/ Acres |
|---|---|---|---|---|---|---|---|---|
| 01 | | 901 | | 931 | 961 | 991 | 1021 | 1051 . ___ |
| 02 | | 902 | | 932 | 962 | 992 | 1022 | 1052 . ___ |
| 03 | | 903 | | 933 | 963 | 993 | 1023 | 1053 . ___ |
| 04 | | 904 | | 934 | 964 | 994 | 1024 | 1054 . ___ |
| 05 | | 905 | | 935 | 965 | 995 | 1025 | 1055 . ___ |
| 06 | | 906 | | 936 | 966 | 996 | 1026 | 1056 . ___ |
| 07 | | 907 | | 937 | 967 | 997 | 1027 | 1057 . ___ |
| 08 | | 908 | | 938 | 968 | 998 | 1028 | 1058 . ___ |
| 09 | | 909 | | 939 | 969 | 999 | 1029 | 1059 . ___ |
| 10 | | 910 | | 940 | 970 | 1000 | 1030 | 1060 . ___ |
| 11 | | 911 | | 941 | 971 | 1001 | 1031 | 1061 . ___ |
| 12 | | 912 | | 942 | 972 | 1002 | 1032 | 1062 . ___ |
| 13 | | 913 | | 943 | 973 | 1003 | 1033 | 1063 . ___ |
| 14 | | 914 | | 944 | 974 | 1004 | 1034 | 1064 . ___ |
| 15 | | 915 | | 945 | 975 | 1005 | 1035 | 1065 . ___ |

*[ENUMERATOR NOTE: If an operation is reported for which no code is on the listing sheet, complete the appropriate line in the table above (leaving out the unknown machine code). Record the line number, the name and a description of the machine below. ]*

LINE NUMBER MACHINE NAME & DESCRIPTION

| OFFICE USE |
|---|
| 010 |

# F IRRIGATION and DRAINAGE F

1. Was this field irrigated for any crop harvested in 1992?

CODE 658

☐ YES - [*Enter* **Code 1**, *and complete table.*] .....

☐ NO - [*Go to Item 2.*]

**IRRIGATION SYSTEM CODES**

**SPRINKLER**
1 CENTER PIVOT
2 LATERAL MOVE
3 HAND-MOVE
4 END-TOW
5 WHEEL MOVE
6 SOLID-SET OR PERMANENT
7 REEL TYPE OR TRAVELING GUN
8 OTHER SPRINKLER (*DESCRIBE*) _____
**GRAVITY**
9 OPEN DITCH WITH CUT OUT
10 OPEN DITCH WITH SIPHON TUBES
11 GATED PIPE
12 GATED PIPE WITH SURGE CONTROL
13 CABLEGATION
14 OTHER GRAVITY (*DESCRIBE*) _____
**DRIP OR TRICKLE**
15 DRIP WITH BUBBLERS
16 DRIP WITHOUT BUBBLERS
17 SUBIRRIGATION
18 OTHER (*DESCRIBE*) _____

**WATER SOURCE CODES**

1 PURCHASED WATER
2 WELLS
3 PONDS
4 LAKES, RIVERS, CANALS
5 RETURN, WASTE WATER AND OTHER WATER

| 1<br>CROP OR LAND USE<br>[*Write In*] | 2<br>CROP CODE | 3<br>How many acres were irrigated in 1992?<br>ACRES | 4<br>What type of irrigation system was used?<br>[*ENTER CODE*] | 5<br>What was the main source of irrigation water?<br>[*ENTER CODE*] | 6<br>What was the average number of inches of water applied per acre in 1992?<br>INCHES |
|---|---|---|---|---|---|
| | 697 | 661 .___ | 664 | 667 | 670 |
| | 698 | 662 .___ | 665 | 668 | 671 |
| | 699 | 663 .___ | 666 | 669 | 672 |

2. How many acres in this field are drained by subsurface (tile) drains? .....

ACRES 696 .___

OFFICE USE 011

# F IRRIGATION F

1. Was this field irrigated for any crop harvested in 1992?

☐ YES - [*Enter Code 1*] ☐ NO - [*Enter Code 2 and go to Section G, Conclusion.*] ..... CODE 658

2. How many acres of each crop were irrigated in this field? ..... ACRES

| | |
|---|---|
| Crop 1 | xx |
| Crop 2 | xx |
| Crop 3 | xx |

3. What type of irrigation system was used? [*Enter code for each crop.*] ..... CODE

| | |
|---|---|
| Crop 1 | xx |
| Crop 2 | xx |
| Crop 3 | xx |

4. What was the source of irrigation water? [*Enter code for each crop.*] ..... CODE

what if crop 1 had two different sources?
Might need to collect acres by source

| | |
|---|---|
| Crop 1 | xx |
| Crop 2 | xx |
| Crop 3 | xx |

5. How many acre-inches of water were applied to each crop? ..... ACRE-INCHES

| | |
|---|---|
| Crop 1 | xx |
| Crop 2 | xx |
| Crop 3 | xx |

Might have to include an irrigation table for those who don't know acre-inches.

| IRRIGATION SYSTEM CODES | |
|---|---|
| CENTER PIVOT | 1 |
| CONVENTIONAL SPRINKLER | 2 |
| CONVENTIONAL GRAVITY | 3 |
| IMPROVED GRAVITY | 4 |
| DRIP OR TRICKLE | 5 |
| SUBIRRIGATION | 6 |
| OTHER (*Describe below*) | 7 |

| WATER SOURCE CODES | |
|---|---|
| WELLS | 1 |
| LAKES, RIVERS, CANALS | 2 |
| RETURN, WASTE WATER AND OTHER WATER | 3 |
| PONDS | 4 |

## G CONCLUSION G

This concludes our interview. Thank you for your cooperation.

*[Review this questionnaire.]*

RESPONDENT

| | |
|---|---|
| OPERATOR / MANAGER | = 1 |
| SPOUSE | = 2 |
| OTHER | = 3 |

CODE 805

RESPONDENT'S NAME _____ PHONE _____

*[Did respondent use farm/ranch records to report the majority of this data? YES = 1; NO = 2]* ..... 806

SUPPLEMENTS USED

FERTILIZER APPLICATIONS → 807

PESTICIDE & CHEMICAL APPLICATIONS → 808

*ENDING TIME [MILITARY]* ..... 809 _ _ _ _

ENUMERATOR ID

ENUMERATOR → 810

DATE MMDDYY 811

EVALUATION 812

**[ENUMERATOR NOTE:**
*If other people (custom applicators, contractors, etc.) were contacted for assistance in completing this questionnaire, please record their names and phone numbers below. Also, use this space for any additional notes or comments.]*

NATIONAL AGRICULTURAL STATISTICS SERVICE

U S Department of Agriculture

Washington, D.C. 20250

# 1992
# JUNE EMAP SURVEY

Authority for collection of information on the June EMAP Survey is Title 7, Section 2204 of the U S Code The information will be used to prepare agricultural estimates Individual reports are confidential Response is voluntary

Form Approved
O.M.B. Number 0535-0089
Approval Expires 5/31/93

Area Version

NORTH CAROLINA

Project Code 920

Segment Number:_____ Tract Letter:_____ County:_____

| State | Stratum | Segment | Tract No |
|---|---|---|---|
| _ _ | _ _ _ _ _ | 00000 | _ _ _ _ _ _ _ 00 |

| OFFICE USE - OPTIONAL | |
|---|---|
| 407 | 408 |

1. I need to make sure we have your (the operator's) correct name and address .

Name of Farm, Ranch, or Operation: _____

Name of Operator: _____
[First] [Middle] [Last]

Address: _____
[Route or Street]

_____
[City] [State] [Zip Code]

Telephone: ( ) -
[Area Code] [Number]

2. On June 1, were the day-to-day decisions for this tract of land made by an individual operator, by partners, or by a hired manager?

☐ [*Individual - enter 1*]

☐ [*Partners - enter number of partners, including operator*] → 921

☐ [*Hired manager - enter 8*]

## PAGE 2

# CROPS AND LAND USES

EMAP

How many acres are inside this blue tract boundary drawn on the photo (map)? _____

Now I would like to ask about each field inside this blue tract boundary and its use during 1992.

| FIELD NUMBER | | | 01 | 02 | 03 | 04 | 05 |
|---|---|---|---|---|---|---|---|
| 1. | Total acres in field | | 828 . | 828 . | 828 . | 828 . | 828 . |
| 2 | Crop or land use (specify) | | | | | | |
| 3. | Occupied farmstead or dwelling | | 843 . | | | | |
| 4. | Woods, roads, ditches, vacant farmstead, etc | | 841 . | 841 . | 841 . | 841 . | 841 . |
| 5. | Pasture | Permanent-not in crop rotation | 842 . | 842 . | 842 . | 842 . | 842 . |
| | | Cropland-used only for pasture | 856 . | 856 . | 856 . | 856 . | 856 . |
| 7. | Idle cropland - idle all during 1992 | | 857 . | 857 . | 857 . | 857 . | 857 . |
| 7a. | Idle cropland in government programs | | 845 . | 845 . | 845 . | 845 . | 845 . |
| 8. | Two crops planted in this field for harvest this year or two uses of the same crop | | [ ] Yes [ ] No | [ ] Yes [ ] No | [ ] Yes [ ] No | [ ] Yes [ ] No | [ ] Yes [ ] No |
| | | (specify second crop or use) | | | | | |
| | | Acres | 844 . | 844 . | 844 . | 844 . | 844 . |
| 9. | Acres left to be planted | | 610 . | 610 . | 618 . | 610 . | 610 . |
| 10. | Acres irrigated and to be irrigated (include double crop acres) | | 620 . | 620 . | 628 . | 620 . | 620 . |
| 15. | Winter Wheat | Planted | 540 . | 540 . | 540 . | 540 . | 540 . |
| 16. | | For grain | 541 . | 541 . | 541 . | 541 . | 541 . |
| 17. | Rye | Planted and to be planted | 547 . | 547 . | 547 . | 547 . | 547 . |
| 18. | | For grain | 548 . | 548 . | 548 . | 548 . | 548 . |
| 19. | Oats | Planted and to be planted | 533 . | 533 . | 533 . | 533 . | 533 . |
| 20 | | For grain | 534 . | 534 . | 534 . | 534 . | 534 . |
| 21. | Barley | Planted and to be planted | 535 . | 535 . | 535 . | 535 . | 535 . |
| 22. | | For grain | 536 . | 536 . | 536 . | 536 . | 536 . |
| 23. | Corn | Planted and to be planted | 530 . | 530 . | 538 . | 530 . | 530 . |
| 24. | | For grain | 531 . | 531 . | 531 . | 531 . | 531 . |
| 26. | Sorghum (exclude crosses with sudan) | Planted and to be planted | 570 . | 570 . | 570 . | 570 . | 570 . |
| 27. | | For grain | 571 . | 571 . | 571 . | 571 . | 571 . |
| 28. | Other uses of grains planted (abandoned, silage, etc.) | Use | | | | | |
| | | Acres | . | . | . | . | . |
| 29. | Hay (cut and to be cut) | Alfalfa and alfalfa mixtures | 653 . | 653 . | 653 . | 653 . | 653 . |
| 30. | | Grain | 656 . | 656 . | 656 . | 656 . | 656 . |
| 32. | | Other hay | 654 . | 654 . | 654 . | 654 . | 654 . |
| 33. | Soybeans | Planted and to be planted | 600 . | 600 . | 600 . | 600 . | 600 . |
| 34. | | Following another crop | 602 . | 602 . | 662 . | 602 . | 602 . |
| 35c. | Tobacco | Burley Acres | 732 . | 732 . | 732 . | 732 . | 732 . |
| 35d. | | Flue-cured Acres | 315 . | 315 . | 315 . | 315 . | 315 . |
| 36 | Peanuts | Planted and to be planted | 690 . | 690 . | 690 . | 690 . | 690 . |
| 38. | Upland Cotton (Net acres if skip rowed) | Planted and to be planted | 524 . | 524 . | 524 . | 524 . | 524 . |
| 46. | Irish Potatoes | Planted and to be planted | 884 . | 884 . | 884 . | 884 . | 884 . |
| 47. | Sweetpotatoes | Planted and to be planted | 558 . | 558 . | 558 . | 558 . | 558 . |
| 48. | Other crops | Acres planted or in use | --- . | --- . | --- . | --- . | --- . |

# CROPS AND LAND USES



[Enter total tract acres] .

| Office Use Total Acres |
|---|
| 00 |
| 840 . |

| FIELD NUMBER | | | 06 | 07 | 08 | 09 |
|---|---|---|---|---|---|---|
| 1. | Total acres in field | | 828 . | 828 . | 828 . | 828 . |
| 2. | Crop or land use [specify] | | | | | |
| | | | | | | |
| 4. | Woods, roads, ditches, vacant farmstead, etc | | 841 . | 841 . | 841 . | 841 . |
| 5. | Pasture | Permanent-not in crop rotation | 842 . | 842 . | 842 . | 842 . |
| | | Cropland-used only for pasture | 856 . | 856 . | 856 . | 856 . |
| 7. | Idle cropland - idle all during 1992 | | 857 . | 857 . | 857 . | 857 . |
| 7a. | Idle cropland in government programs | | 845 . | 845 . | 845 . | 845 . |
| 8. | Two crops planted in this field for harvest this year or two uses of the same crop | | [ ] Yes [ ] No | [ ] Yes [ ] No | [ ] Yes [ ] No | [ ] Yes [ ] No |
| | [specify second crop or use] | | | | | |
| | | Acres | 844 . | 844 . | 844 . | 844 . |
| 9. | Acres left to be planted | | 610 . | 610 . | 610 . | 610 . |
| 10. | Acres irrigated and to be irrigated [include double crop acres] | | 620 . | 620 . | 620 . | 620 . |
| 15. | Winter Wheat | Planted | 540 . | 540 . | 540 . | 540 . |
| 16. | | For grain | 541 . | 541 . | 541 . | 541 . |
| 17. | Rye | Planted and to be planted | 547 . | 547 . | 547 . | 547 . |
| 18. | | For grain | 548 . | 548 . | 548 . | 548 . |
| 19. | Oats | Planted and to be planted | 533 . | 533 . | 533 . | 533 . |
| 20. | | For grain | 534 . | 534 . | 534 . | 534 . |
| 21. | Barley | Planted and to be planted | 535 . | 535 . | 535 . | 535 . |
| 22. | | For grain | 536 . | 536 . | 536 . | 536 . |
| 23. | Corn | Planted and to be planted | 530 . | 530 . | 530 . | 530 . |
| 24. | | For grain | 531 . | 531 . | 531 . | 531 . |
| 26 | Sorghum [exclude crosses with sudan] | Planted and to be planted | 570 . | 570 . | 570 . | 570 . |
| 27. | | For grain | 571 . | 571 . | 571 . | 571 . |
| 28. | Other uses of grains planted (abandoned, silage, etc.) | Use | | | | |
| | | Acres | . | . | . | . |
| 29. | Hay (cut and to be cut) | Alfalfa and alfalfa mixtures | 653 . | 653 . | 653 . | 653 . |
| 30. | | Grain | 656 . | 656 . | 656 . | 656 . |
| 32. | | Other hay | 654 . | 654 . | 654 . | 654 . |
| 33. | Soybeans | Planted and to be planted | 600 . | 600 . | 600 . | 600 . |
| 34 | | Following another crop | 602 . | 602 . | 602 . | 602 . |
| 35c. | Tobacco | Burley Acres | 732 . | 732 . | 732 . | 732 . |
| 35d. | | Flue-cured Acres | 315 . | 315 . | 315 . | 315 . |
| 36. | Peanuts | Planted and to be planted | 690 . | 690 . | 690 . | 690 . |
| 38. | Upland Cotton [Net acres if skip rowed] | Planted and to be planted | 524 . | 524 . | 524 . | 524 . |
| 46. | Irish Potatoes | Planted and to be planted | 884 . | 884 . | 884 . | 884 . |
| 47. | Sweetpotatoes | Planted and to be planted | 558 . | 558 . | 558 . | 558 . |
| 48. | Other crops | Acres planted or in use | — — — . | — — — . | — — — . | — — — . |

## CROPS AND LAND USE (Continued)

[Refer to photo and point out blue tract boundaries]

51. Inside these blue lines, is there a pond, either constructed or naturally formed, used to provide water for livestock, fish and wildlife, irrigation, or other related uses?

☐ YES ☐ DON'T KNOW = 2 ☐ NO = 3 — [Enter code then go to Item 52] → 803

↓ 805

51a. How many? _____

51b. At any time during 1992, will any of them be used for irrigation water? 806

☐ YES = 1 ☐ DON'T KNOW = 2 ☐ NO = 3 — [Enter code] →

52. Are there any water wells, drilled or dug for any purpose, inside the blue lines? 807

☐ YES ☐ DON'T KNOW = 2 ☐ NO = 3 — [Enter code then go to Total Acres Operated] →

↓ 809

52a. How many? _____

52b. At any time during 1992, will any of them be used for irrigation water? 810

☐ YES = 1 ☐ DON'T KNOW = 2 ☐ NO = 3 — [Enter code] →

## TOTAL ACRES OPERATED

[IF HIRED MANAGER CHECKED ON FACE PAGE (921 = 8), GO TO ITEM 2]

1. Now I would like to ask about the total acres operated under this land arrangement. Include farmstead, all cropland, woodland, pastureland, wasteland, and government program land.

1a. On June 1, how many acres did this operation own? + 901 .

1b. Rent from others? [Exclude land used on an animal unit month (AUM) basis] + 902 .

1d. Rent to others? − 905 .

1e. Then the total acres operated under this arrangement was ITEM 1a + 1b - 1d : = 900 .

[GO TO ITEM 3]

2. Now I would like to ask about the total acres operated as a hired manager.
On June 1, how many acres were operated for others as a hired manager under this land arrangement? 904

3. Does this include the farmstead, all cropland, woodland, pastureland, wasteland, and government program land? [If not, make corrections]

## CONCLUSION

[Check type of respondent and enter code]

☐ Operator / Manager . . . . . = 1
☐ Spouse . . . . . = 2
☐ Other [Enter name below] = 3
☐ Obs R . . . . . = 4
☐ Obs NR . . . . . = 5
☐ Part Int . . . . . = 6

→ 101

[Record name of respondent if not the operator or spouse] _____

Enumerator: _____

Date: _____

[Notes about respondent's answers or other data collection problems]

| May | June | June |
|---|---|---|
| 28 149 | 03-155 | 10-162 |
| 29-150 | 04-156 | 11-163 |
| 30-151 | 05-157 | 12-164 |
| 31-152 | 06-158 | 13-165 |
| June | 07-159 | 14-166 |
| 01-153 | 08 160 | 15-167 |
| 02 154 | 09 161 | |

Enumerator ID: 098

Julian Date: 987

Office Use Quality Rating: 100

## APPENDIX 6
ENUMERATOR MANUAL FOR SAMPLING SOIL

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

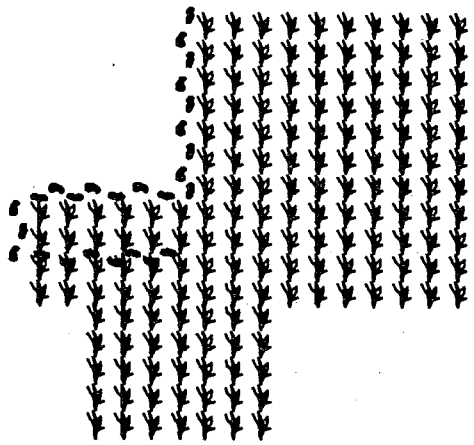

**Figure 1.** Starting point in odd-shaped fields.

The point of entry into the field will be the first corner of the field which is reached when approaching the field. If the field has NO definite corners, enter the field from the point which is most accessible by car. Remember that the point or corner selected for entry into the field MUST allow an opportunity for the units to fall ANYWHERE within the sample field boundaries (excluding Form A deductions) following the procedures outlined in the manual. If the field has been selected for more than one sample, the second closest corner to the starting corner will be used as the starting corner for the second sample number. Every sixth field will have two samples and the second sample will be double-sampled.

The following steps outline procedures to follow when locating and laying out sample units.

| | |
|---|---|
| STEP 1 | Determine the starting corner. This will be the first corner of the field which is reached when approaching the field. |
| STEP 2 | Walk along the end of the field the required number of paces (steps). This will be your entry point into the field. |
| STEP 3 | Then walk the specified number of paces (steps) into the field. Start your first pace about one and one-half feet outside the plowed edge of the field. |
| *IMPORTANT* | If you cross any of the acres deducted as "Other Uses" on the Form A while you are counting paces, 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 row and pace count. |
| *EXCEPTIONS* | 1. "Bounce back". When pacing along the edge of the field, or pacing into the field, you reach the opposite end or side of the field and still have not taken the required number of paces, turn around and walk back in the direction from which you came until the required number of paces has been stepped off. |

2. Odd-Shaped fields. The bounce-back rule applies. However, as in Figure 1, you should count paces only while walking in the initial direction. If the field border takes an abrupt turn, follow the border, but do not count paces that are not in the initial direction of walking. Then count paces into the field in the usual way.

3. Edges. If the random starting point lands at a corner or an edge, turn at 90-degree increments to your right until the sampling transect fits within the field.

STEP 4 — After you have taken the last of the required paces, place a yellow stake at the toe of your shoe. Lay the right-angle on the ground with the red point touching the stake. Place a second yellow stake at the right corner of the right-angle.

STEP 5 — Flip the right-angle 180° and place a third yellow stake in the corner of the right-angle to form a straight line with all three stakes (Figure 2).

STEP 6 — Beginning at the center stake, take two and one-half paces, staying in a straight line with the three yellow stakes. Place a red stake at the toe of your shoe. Consider this stake 1.

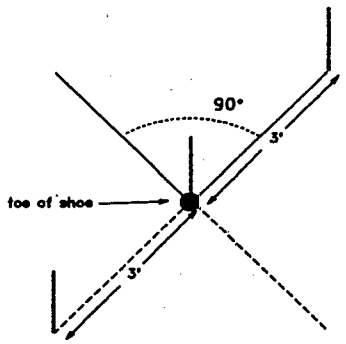


**Figure 2.** Placement of yellow reference stakes at center of transect.

*IMPORTANT* — Carry the right-angle and 10 red stakes with you will pacing off transect for sampling soil for later use in sampling soil.

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

STEP 8 — Repeat step 7 until 10 red stakes have been inserted into the soil since the original center stake. The transect should be diagonal across rows (Figure 3).

*IMPORTANT* — If you reach a border of the field while walking along the diagonal transect, turn a 90-degree angle and proceed with your paces and inserting stakes. Repeat the 90-degree rule for each border encountered (Figure 4).

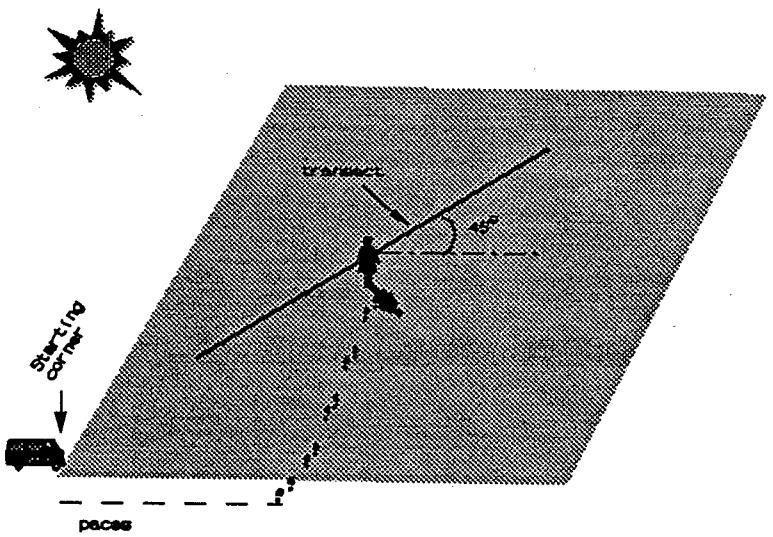


**Figure 3.** View of entire diagonal transect across the sampling area.

STEP 9 — From the last stake (number 10), take 1 soil core 3' (marked red on th right-angle) from the red stake measuring away from the yellow reference stakes. Take 2 cores at each stake if the field is classified as double-sampled. Pull the stake after taking the soil core.

STEP 10 — Repeat step 9 for the remaining stakes walking toward the original yellow reference stakes for all even-numbered stakes; otherwise take the soil sample 1.5' from the red stake.

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

STEP 11 — Beginning at the center stake reverse your direction and repeat steps 6 through 10.

STEP 12 — Remove all stakes and exit field.

*IMPORTANT* — Make sure all stakes, soil probe, and bucket are free of soil before leaving the field area. Rinse all equipment thoroughly with water.

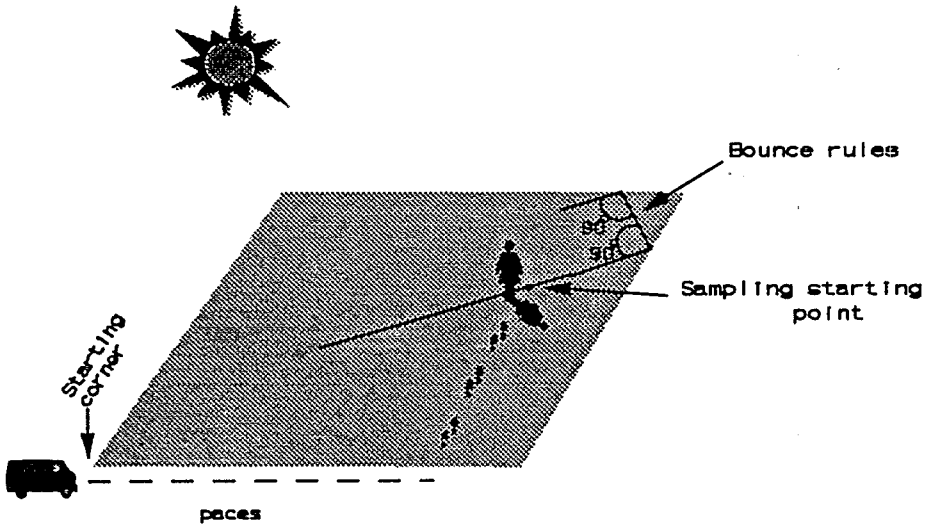


**Figure 4. Bounce-rule of 90-degrees for each border encountered.**

## 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 entire 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; for some soils, a large screwdriver can be used 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 it is impossible to reach 8" depth with the tube, collect at least 4" deep cores and an additional core to result in the same volume that 20-8" deep cores would provide; record the problem on the survey form. Do not accept cores less than 4" in length. Combine all cores sampled per transect in the bucket (20 cores for regular samples, 40-cores for double-samples).

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 (2 notches), mini tip (1 notch) and super duty tip (3 notches) are for sampling moist, dry, and stony soils, respectively. A "wrench" for changing tips is included in each probe set.

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.

## III. LABELLING AND TRANSPORTING THE SAMPLE

When all cores have been deposited into the bucket for 1 composite sample, break up the clumps *gently* (excessive pressure or mechanical abrasion may kill nematodes). Mix the soil thoroughly. Fill the plastic beaker to the surface with soil and pour into a plastic bag marked "A" and close the bag with a wire tag with the appropriate sample number.

Transfer the rest of the soil (large sample) into a plastic bag marked "B" and close with the wire tag with the appropriate sample number. Note that double-samples will have two wire tags.

*IMPORTANT* Record the date collected, date mailed, and enumerator code on the bag labels and associated postcard for the field.

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

Mail the beaker (small) sample in the small mailing envelope marked with an "A" and the large sample in the large mailing envelope marked with a "B" using Federal Express overnight-delivery. Mail one sample per container using the pre-addressed, postage-paid envelopes provided. Use strapping tape to close the mailing envelopes. Samples can be dropped-off at the county Soil Conservation Service office. You may also arrange to have samples picked up at a residence or office address. All samples should be mailed on the same day of sampling or first thing the following day. For pickup, call Federal Express at 1-800-238-5355. 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 same 1-800 number and providing the zipcode for the pickup address.

For example, some pick-up deadlines are:

| | |
|---|---|
| Raleigh | M-F 6 pm, SAT 4 pm |
| Gates | M-F 12 noon, no SAT pickup |
| Danbury | M-F 12 noon, SAT 12 noon |
| Brevard | M-F 4 pm, no SAT pickup |
| New Hope | M-F 2:30 pm, no SAT pickup |

It is important to keep the samples in a cooler until they are picked up. If you must store the samples over a weekend, keep them indoors at room temperature or in a cooler.

Mail completed postcards at a nearby post office.

## APPENDIX 7
## Sample Identification for QA/QC Procedures

The following table illustrates the information that will accompany coordinates of each segment sampled in the Pilot. Each sample sent to an analysis laboratory will be assigned an arbitrary number between 1-447. This number will not reveal anything about the location where the sample was collected or whether the sample is a duplicate or known blank for quality assurance determination. This procedure is necessary to acquire unbiased results from analysis. A database will include at least the parameters listed in the table plus actual sampling coordinates to permit proper identification of samples after analyses are completed.

| Design[a] | Segment[b] | Field[c] | Lab Sample[d] | 2nd Transect[e] | Lab Dup[f] | Known[g] |
|---|---|---|---|---|---|---|
| RP | 1 | 1 | 1 | 1 | 0 | 0 |
| RP | 1 | 2 | 2 | 1 | 0 | 0 |
| RP | 1 | 3 | 3 | 1 | 0 | 0 |
| RP | 2 | 4 | 4 | 1 | 0 | 0 |
| RP | 2 | 5 | 5 | 1 | 0 | 0 |
| RP | 2 | 6 | 6 | 2 | 0 | 0 |
| RP | 2 | 6 | 7 | 2 | 0 | 0 |
| RP | 3 | 7 | 8 | 1 | 0 | 0 |
| RP | 3 | 8 | 9 | 1 | 0 | 0 |
| RP | 3 | 9 | 10 | 1 | 0 | 0 |
| RP | 4 | 10 | 11 | 1 | 0 | 0 |
| RP | 4 | 11 | 12 | 1 | 0 | 0 |
| RP | 4 | 12 | 13 | 2 | 0 | 0 |
| RP | 4 | 12 | 14 | 2 | 1 | 0 |
| RP | 4 | 12 | 15 | 2 | 2 | 0 |
| RP | 5 | 13 | 16 | 1 | 0 | 0 |
| RP | 5 | 14 | 17 | 1 | 0 | 0 |
| RP | 5 | 15 | 18 | 1 | 0 | 0 |
| RP | 6 | 16 | 19 | 1 | 0 | 0 |
| RP | 6 | 17 | 20 | 1 | 0 | 0 |
| RP | 6 | 18 | 21 | 2 | 0 | 0 |
| RP | 6 | 18 | 22 | 2 | 0 | 0 |
| RP | 7 | 19 | 23 | 1 | 0 | 0 |
| RP | 7 | 20 | 24 | 1 | 0 | 0 |
| RP | 7 | 21 | 25 | 1 | 0 | 0 |
| RP | 8 | 22 | 26 | 1 | 0 | 0 |
| RP | 8 | 23 | 27 | 1 | 0 | 0 |
| RP | 8 | 24 | 28 | 2 | 0 | 0 |
| RP | 8 | 24 | 29 | 2 | 1 | 0 |
| RP | 8 | 24 | 30 | 2 | 2 | 0 |
| RP | 9 | 25 | 31 | 1 | 0 | 0 |
| RP | 9 | 26 | 32 | 1 | 0 | 0 |
| RP | 9 | 27 | 33 | 1 | 0 | 0 |
| RP | 10 | 28 | 34 | 1 | 0 | 0 |
| RP | 10 | 29 | 35 | 1 | 0 | 0 |
| RP | 10 | 30 | 36 | 2 | 0 | 0 |
| RP | 10 | 30 | 37 | 2 | 0 | 0 |
| RP | 11 | 31 | 38 | 1 | 0 | 0 |
| RP | 11 | 32 | 39 | 1 | 0 | 0 |
| RP | 9999[h] | 9999 | 40 | 9999 | 9999 | 1 |
| RP | 11 | 33 | 41 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RP | 12 | 34 | 42 | 1 | 0 | 0 |
| RP | 12 | 35 | 43 | 1 | 0 | 0 |
| RP | 12 | 36 | 44 | 2 | 0 | 0 |
| RP | 12 | 36 | 45 | 2 | 1 | 0 |
| RP | 12 | 36 | 46 | 2 | 2 | 0 |
| RP | 13 | 37 | 47 | 1 | 0 | 0 |
| RP | 13 | 38 | 48 | 1 | 0 | 0 |
| RP | 13 | 39 | 49 | 1 | 0 | 0 |
| RP | 14 | 40 | 50 | 1 | 0 | 0 |
| RP | 14 | 41 | 51 | 1 | 0 | 0 |
| RP | 14 | 42 | 52 | 2 | 0 | 0 |
| RP | 14 | 42 | 53 | 2 | 0 | 0 |
| RP | 15 | 43 | 54 | 1 | 0 | 0 |
| RP | 15 | 44 | 55 | 1 | 0 | 0 |
| RP | 15 | 45 | 56 | 1 | 0 | 0 |
| RP | 16 | 46 | 57 | 1 | 0 | 0 |
| RP | 16 | 47 | 58 | 1 | 0 | 0 |
| RP | 16 | 48 | 59 | 2 | 0 | 0 |
| RP | 16 | 48 | 60 | 2 | 1 | 0 |
| RP | 16 | 48 | 61 | 2 | 2 | 0 |
| RP | 17 | 49 | 62 | 1 | 0 | 0 |
| RP | 17 | 50 | 63 | 1 | 0 | 0 |
| RP | 17 | 51 | 64 | 1 | 0 | 0 |
| RP | 18 | 52 | 65 | 1 | 0 | 0 |
| RP | 18 | 53 | 66 | 1 | 0 | 0 |
| RP | 18 | 54 | 67 | 2 | 0 | 0 |
| RP | 18 | 54 | 68 | 2 | 0 | 0 |
| RP | 19 | 55 | 69 | 1 | 0 | 0 |
| RP | 19 | 56 | 70 | 1 | 0 | 0 |
| RP | 19 | 57 | 71 | 1 | 0 | 0 |
| RP | 20 | 58 | 72 | 1 | 0 | 0 |
| RP | 20 | 59 | 73 | 1 | 0 | 0 |
| RP | 20 | 60 | 74 | 2 | 0 | 0 |
| RP | 20 | 60 | 75 | 2 | 1 | 0 |
| RP | 20 | 60 | 76 | 2 | 2 | 0 |
| RP | 21 | 61 | 77 | 1 | 0 | 0 |
| RP | 21 | 62 | 78 | 1 | 0 | 0 |
| RP | 21 | 63 | 79 | 1 | 0 | 0 |
| RP | 9999 | 9999 | 80 | 9999 | 9999 | 1 |
| RP | 22 | 64 | 81 | 1 | 0 | 0 |
| RP | 22 | 65 | 82 | 1 | 0 | 0 |
| RP | 22 | 66 | 83 | 2 | 0 | 0 |
| RP | 22 | 66 | 84 | 2 | 0 | 0 |
| RP | 23 | 67 | 85 | 1 | 0 | 0 |
| RP | 23 | 68 | 86 | 1 | 0 | 0 |
| RP | 23 | 69 | 87 | 1 | 0 | 0 |
| RP | 24 | 70 | 88 | 1 | 0 | 0 |
| RP | 24 | 71 | 89 | 1 | 0 | 0 |
| RP | 24 | 72 | 90 | 2 | 0 | 0 |
| RP | 24 | 72 | 91 | 2 | 1 | 0 |
| RP | 24 | 72 | 92 | 2 | 2 | 0 |
| RP | 25 | 73 | 93 | 1 | 0 | 0 |
| RP | 25 | 74 | 94 | 1 | 0 | 0 |
| RP | 25 | 75 | 95 | 1 | 0 | 0 |
| RP | 26 | 76 | 96 | 1 | 0 | 0 |
| RP | 26 | 77 | 97 | 1 | 0 | 0 |
| RP | 26 | 78 | 98 | 2 | 0 | 0 |
| RP | 26 | 78 | 99 | 2 | 0 | 0 |
| RP | 27 | 79 | 100 | 1 | 0 | 0 |
| RP | 27 | 80 | 101 | 1 | 0 | 0 |
| RP | 27 | 81 | 102 | 1 | 0 | 0 |
| RP | 28 | 82 | 103 | 1 | 0 | 0 |

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|---|---|---|---|---|---|---|
| RP | 28 | 83 | 104 | 1 | 0 | 0 |
| RP | 28 | 84 | 105 | 2 | 0 | 0 |
| RP | 28 | 84 | 106 | 2 | 1 | 0 |
| RP | 28 | 84 | 107 | 2 | 2 | 0 |
| RP | 29 | 85 | 108 | 1 | 0 | 0 |
| RP | 29 | 86 | 109 | 1 | 0 | 0 |
| RP | 29 | 87 | 110 | 1 | 0 | 0 |
| RP | 30 | 88 | 111 | 1 | 0 | 0 |
| RP | 30 | 89 | 112 | 1 | 0 | 0 |
| RP | 30 | 90 | 113 | 2 | 0 | 0 |
| RP | 30 | 90 | 114 | 2 | 0 | 0 |
| RP | 31 | 91 | 115 | 1 | 0 | 0 |
| RP | 31 | 92 | 116 | 1 | 0 | 0 |
| RP | 31 | 93 | 117 | 1 | 0 | 0 |
| RP | 32 | 94 | 118 | 1 | 0 | 0 |
| RP | 32 | 95 | 119 | 1 | 0 | 0 |
| RP | 9999 | 9999 | 120 | 9999 | 9999 | 1 |
| RP | 32 | 96 | 121 | 2 | 0 | 0 |
| RP | 32 | 96 | 122 | 2 | 1 | 0 |
| RP | 32 | 96 | 123 | 2 | 2 | 0 |
| RP | 33 | 97 | 124 | 1 | 0 | 0 |
| RP | 33 | 98 | 125 | 1 | 0 | 0 |
| RP | 33 | 99 | 126 | 1 | 0 | 0 |
| RP | 34 | 100 | 127 | 1 | 0 | 0 |
| RP | 34 | 101 | 128 | 1 | 0 | 0 |
| RP | 34 | 102 | 129 | 2 | 0 | 0 |
| RP | 34 | 102 | 130 | 2 | 0 | 0 |
| RP | 35 | 103 | 131 | 1 | 0 | 0 |
| RP | 35 | 104 | 132 | 1 | 0 | 0 |
| RP | 35 | 105 | 133 | 1 | 0 | 0 |
| RP | 36 | 106 | 134 | 1 | 0 | 0 |
| RP | 36 | 107 | 135 | 1 | 0 | 0 |
| RP | 36 | 108 | 136 | 2 | 0 | 0 |
| RP | 36 | 108 | 137 | 2 | 1 | 0 |
| RP | 36 | 108 | 138 | 2 | 2 | 0 |
| RP | 37 | 109 | 139 | 1 | 0 | 0 |
| RP | 37 | 110 | 140 | 1 | 0 | 0 |
| RP | 37 | 111 | 141 | 1 | 0 | 0 |
| RP | 38 | 112 | 142 | 1 | 0 | 0 |
| RP | 38 | 113 | 143 | 1 | 0 | 0 |
| RP | 38 | 114 | 144 | 2 | 0 | 0 |
| RP | 38 | 114 | 145 | 2 | 0 | 0 |
| RP | 39 | 115 | 146 | 1 | 0 | 0 |
| RP | 39 | 116 | 147 | 1 | 0 | 0 |
| RP | 39 | 117 | 148 | 1 | 0 | 0 |
| RP | 40 | 118 | 149 | 1 | 0 | 0 |
| RP | 40 | 119 | 150 | 1 | 0 | 0 |
| RP | 40 | 120 | 151 | 2 | 0 | 0 |
| RP | 40 | 120 | 152 | 2 | 1 | 0 |
| RP | 40 | 120 | 153 | 2 | 2 | 0 |
| RP | 41 | 121 | 154 | 1 | 0 | 0 |
| RP | 41 | 122 | 155 | 1 | 0 | 0 |
| RP | 41 | 123 | 156 | 1 | 0 | 0 |
| RP | 42 | 124 | 157 | 1 | 0 | 0 |
| RP | 42 | 125 | 158 | 1 | 0 | 0 |
| RP | 42 | 126 | 159 | 2 | 0 | 0 |
| RP | 9999 | 9999 | 160 | 9999 | 9999 | 1 |
| RP | 42 | 126 | 161 | 2 | 0 | 0 |
| RP | 43 | 127 | 162 | 1 | 0 | 0 |
| RP | 43 | 128 | 163 | 1 | 0 | 0 |
| RP | 43 | 129 | 164 | 1 | 0 | 0 |
| RP | 44 | 130 | 165 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RP | 44 | 131 | 166 | 1 | 0 | 0 |
| RP | 44 | 132 | 167 | 2 | 0 | 0 |
| RP | 44 | 132 | 168 | 2 | 1 | 0 |
| RP | 44 | 132 | 169 | 2 | 2 | 0 |
| RP | 45 | 133 | 170 | 1 | 0 | 0 |
| RP | 45 | 134 | 171 | 1 | 0 | 0 |
| RP | 45 | 135 | 172 | 1 | 0 | 0 |
| RP | 46 | 136 | 173 | 1 | 0 | 0 |
| RP | 46 | 137 | 174 | 1 | 0 | 0 |
| RP | 46 | 138 | 175 | 2 | 0 | 0 |
| RP | 46 | 138 | 176 | 2 | 0 | 0 |
| RP | 47 | 139 | 177 | 1 | 0 | 0 |
| RP | 47 | 140 | 178 | 1 | 0 | 0 |
| RP | 47 | 141 | 179 | 1 | 0 | 0 |
| RP | 48 | 142 | 180 | 1 | 0 | 0 |
| RP | 48 | 143 | 181 | 1 | 0 | 0 |
| RP | 48 | 144 | 182 | 2 | 0 | 0 |
| RP | 48 | 144 | 183 | 2 | 1 | 0 |
| RP | 48 | 144 | 184 | 2 | 2 | 0 |
| RP | 49 | 145 | 185 | 1 | 0 | 0 |
| RP | 49 | 146 | 186 | 1 | 0 | 0 |
| RP | 49 | 147 | 187 | 1 | 0 | 0 |
| RP | 50 | 148 | 188 | 1 | 0 | 0 |
| RP | 50 | 149 | 189 | 1 | 0 | 0 |
| RP | 50 | 150 | 190 | 2 | 0 | 0 |
| RP | 50 | 150 | 191 | 2 | 0 | 0 |
| RP | 51 | 151 | 192 | 1 | 0 | 0 |
| RP | 51 | 152 | 193 | 1 | 0 | 0 |
| RP | 51 | 153 | 194 | 1 | 0 | 0 |
| RP | 52 | 154 | 196 | 1 | 0 | 0 |
| RP | 52 | 155 | 197 | 1 | 0 | 0 |
| RP | 52 | 156 | 198 | 2 | 0 | 0 |
| RP | 52 | 156 | 199 | 2 | 1 | 0 |
| RP | 9999 | 9999 | 200 | 9999 | 9999 | 1 |
| RP | 52 | 156 | 201 | 2 | 2 | 0 |
| RP | 53 | 157 | 202 | 1 | 0 | 0 |
| RP | 53 | 158 | 203 | 1 | 0 | 0 |
| RP | 53 | 159 | 204 | 1 | 0 | 0 |
| RP | 54 | 160 | 205 | 1 | 0 | 0 |
| RP | 54 | 161 | 206 | 1 | 0 | 0 |
| RP | 54 | 162 | 207 | 2 | 0 | 0 |
| RP | 54 | 162 | 208 | 2 | 0 | 0 |
| RP | 55 | 163 | 209 | 1 | 0 | 0 |
| RP | 55 | 164 | 210 | 1 | 0 | 0 |
| RP | 55 | 165 | 211 | 1 | 0 | 0 |
| RP | 56 | 166 | 212 | 1 | 0 | 0 |
| RP | 56 | 167 | 213 | 1 | 0 | 0 |
| RP | 56 | 168 | 214 | 2 | 0 | 0 |
| RP | 56 | 168 | 215 | 2 | 1 | 0 |
| RP | 56 | 168 | 216 | 2 | 2 | 0 |
| RP | 57 | 169 | 217 | 1 | 0 | 0 |
| RP | 57 | 170 | 218 | 1 | 0 | 0 |
| RP | 57 | 171 | 219 | 1 | 0 | 0 |
| RP | 58 | 172 | 220 | 1 | 0 | 0 |
| RP | 58 | 173 | 221 | 1 | 0 | 0 |
| RP | 58 | 174 | 222 | 2 | 0 | 0 |
| RP | 58 | 174 | 223 | 2 | 0 | 0 |
| RP | 59 | 175 | 224 | 1 | 0 | 0 |
| RP | 59 | 176 | 225 | 1 | 0 | 0 |
| RP | 59 | 177 | 226 | 1 | 0 | 0 |
| RP | 60 | 178 | 227 | 1 | 0 | 0 |
| RP | 60 | 179 | 228 | 1 | 0 | 0 |

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|---|---|---|---|---|---|---|
| RP | 60 | 180 | 229 | 2 | 0 | 0 |
| RP | 60 | 180 | 230 | 2 | 1 | 0 |
| RP | 60 | 180 | 231 | 2 | 2 | 0 |
| RP | 61 | 181 | 232 | 1 | 0 | 0 |
| RP | 61 | 182 | 233 | 1 | 0 | 0 |
| RP | 61 | 183 | 234 | 1 | 0 | 0 |
| RP | 62 | 184 | 235 | 1 | 0 | 0 |
| RP | 62 | 185 | 236 | 1 | 0 | 0 |
| RP | 62 | 186 | 237 | 2 | 0 | 0 |
| RP | 62 | 186 | 238 | 2 | 0 | 0 |
| RP | 63 | 187 | 239 | 1 | 0 | 0 |
| RP | 9999 | 9999 | 240 | 9999 | 9999 | 1 |
| RP | 63 | 188 | 241 | 1 | 0 | 0 |
| RP | 63 | 189 | 242 | 1 | 0 | 0 |
| RP | 64 | 190 | 243 | 1 | 0 | 0 |
| RP | 64 | 191 | 244 | 1 | 0 | 0 |
| RP | 64 | 192 | 245 | 2 | 0 | 0 |
| RP | 64 | 192 | 246 | 2 | 1 | 0 |
| RP | 64 | 192 | 247 | 2 | 2 | 0 |
| RP | 65 | 193 | 248 | 1 | 0 | 0 |
| RP | 65 | 194 | 249 | 1 | 0 | 0 |
| RP | 65 | 195 | 250 | 1 | 0 | 0 |
| | | | | | | |
| HEX | 1 | 1 | 251 | 1 | 0 | 0 |
| HEX | 1 | 2 | 252 | 1 | 0 | 0 |
| HEX | 1 | 3 | 253 | 2 | 0 | 0 |
| HEX | 1 | 3 | 254 | 2 | 0 | 0 |
| HEX | 2 | 4 | 255 | 1 | 0 | 0 |
| HEX | 2 | 5 | 256 | 1 | 0 | 0 |
| HEX | 2 | 6 | 257 | 1 | 0 | 0 |
| HEX | 3 | 7 | 258 | 1 | 0 | 0 |
| HEX | 3 | 8 | 259 | 1 | 0 | 0 |
| HEX | 3 | 9 | 260 | 2 | 0 | 0 |
| HEX | 3 | 9 | 261 | 2 | 1 | 0 |
| HEX | 3 | 9 | 262 | 2 | 2 | 0 |
| HEX | 4 | 10 | 263 | 1 | 0 | 0 |
| HEX | 4 | 11 | 264 | 1 | 0 | 0 |
| HEX | 4 | 12 | 265 | 1 | 0 | 0 |
| HEX | 5 | 13 | 266 | 1 | 0 | 0 |
| HEX | 5 | 14 | 267 | 1 | 0 | 0 |
| HEX | 5 | 15 | 268 | 2 | 0 | 0 |
| HEX | 5 | 15 | 269 | 2 | 0 | 0 |
| HEX | 6 | 16 | 270 | 1 | 0 | 0 |
| HEX | 6 | 17 | 271 | 1 | 0 | 0 |
| HEX | 6 | 18 | 272 | 1 | 0 | 0 |
| HEX | 7 | 19 | 273 | 1 | 0 | 0 |
| HEX | 7 | 20 | 274 | 1 | 0 | 0 |
| HEX | 7 | 21 | 275 | 2 | 0 | 0 |
| HEX | 7 | 21 | 276 | 2 | 1 | 0 |
| HEX | 7 | 21 | 277 | 2 | 2 | 0 |
| HEX | 8 | 22 | 278 | 1 | 0 | 0 |
| HEX | 8 | 23 | 279 | 1 | 0 | 0 |
| HEX | 9999 | 9999 | 280 | 9999 | 9999 | 1 |
| HEX | 8 | 24 | 281 | 1 | 0 | 0 |
| HEX | 9 | 25 | 282 | 1 | 0 | 0 |
| HEX | 9 | 26 | 283 | 1 | 0 | 0 |
| HEX | 9 | 27 | 284 | 2 | 0 | 0 |
| HEX | 9 | 27 | 285 | 2 | 0 | 0 |
| HEX | 10 | 28 | 286 | 1 | 0 | 0 |
| HEX | 10 | 29 | 287 | 1 | 0 | 0 |
| HEX | 10 | 30 | 288 | 1 | 0 | 0 |
| HEX | 11 | 31 | 289 | 1 | 0 | 0 |

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|---|---|---|---|---|---|---|
| HEX | 11 | 32 | 290 | 1 | 0 | 0 |
| HEX | 11 | 33 | 291 | 2 | 0 | 0 |
| HEX | 11 | 33 | 292 | 2 | 1 | 0 |
| HEX | 11 | 33 | 293 | 2 | 2 | 0 |
| HEX | 12 | 34 | 294 | 1 | 0 | 0 |
| HEX | 12 | 35 | 295 | 1 | 0 | 0 |
| HEX | 12 | 36 | 296 | 1 | 0 | 0 |
| HEX | 13 | 37 | 297 | 1 | 0 | 0 |
| HEX | 13 | 38 | 298 | 1 | 0 | 0 |
| HEX | 13 | 39 | 299 | 2 | 0 | 0 |
| HEX | 13 | 39 | 300 | 2 | 0 | 0 |
| HEX | 14 | 40 | 301 | 1 | 0 | 0 |
| HEX | 14 | 41 | 302 | 1 | 0 | 0 |
| HEX | 14 | 42 | 303 | 1 | 0 | 0 |
| HEX | 15 | 43 | 304 | 1 | 0 | 0 |
| HEX | 15 | 44 | 305 | 1 | 0 | 0 |
| HEX | 15 | 45 | 306 | 2 | 0 | 0 |
| HEX | 15 | 45 | 307 | 2 | 1 | 0 |
| HEX | 15 | 45 | 308 | 2 | 2 | 0 |
| HEX | 16 | 46 | 309 | 1 | 0 | 0 |
| HEX | 16 | 47 | 310 | 1 | 0 | 0 |
| HEX | 16 | 48 | 311 | 1 | 0 | 0 |
| HEX | 17 | 49 | 312 | 1 | 0 | 0 |
| HEX | 17 | 50 | 313 | 1 | 0 | 0 |
| HEX | 17 | 51 | 314 | 2 | 0 | 0 |
| HEX | 17 | 51 | 315 | 2 | 0 | 0 |
| HEX | 18 | 52 | 316 | 1 | 0 | 0 |
| HEX | 18 | 53 | 317 | 1 | 0 | 0 |
| HEX | 18 | 54 | 318 | 1 | 0 | 0 |
| HEX | 19 | 55 | 319 | 1 | 0 | 0 |
| HEX | 9999 | 9999 | 320 | 9999 | 9999 | 1 |
| HEX | 19 | 56 | 321 | 1 | 0 | 0 |
| HEX | 19 | 57 | 322 | 2 | 0 | 0 |
| HEX | 19 | 57 | 323 | 2 | 1 | 0 |
| HEX | 19 | 57 | 324 | 2 | 2 | 0 |
| HEX | 20 | 58 | 325 | 1 | 0 | 0 |
| HEX | 20 | 59 | 326 | 1 | 0 | 0 |
| HEX | 20 | 60 | 327 | 1 | 0 | 0 |
| HEX | 21 | 61 | 328 | 1 | 0 | 0 |
| HEX | 21 | 62 | 329 | 1 | 0 | 0 |
| HEX | 21 | 63 | 330 | 2 | 0 | 0 |
| HEX | 21 | 63 | 331 | 2 | 0 | 0 |
| HEX | 22 | 64 | 332 | 1 | 0 | 0 |
| HEX | 22 | 65 | 333 | 1 | 0 | 0 |
| HEX | 22 | 66 | 334 | 1 | 0 | 0 |
| HEX | 23 | 67 | 335 | 1 | 0 | 0 |
| HEX | 23 | 68 | 336 | 1 | 0 | 0 |
| HEX | 23 | 69 | 337 | 2 | 0 | 0 |
| HEX | 23 | 69 | 338 | 2 | 1 | 0 |
| HEX | 23 | 69 | 339 | 2 | 2 | 0 |
| HEX | 24 | 70 | 340 | 1 | 0 | 0 |
| HEX | 24 | 71 | 341 | 1 | 0 | 0 |
| HEX | 24 | 72 | 342 | 1 | 0 | 0 |
| HEX | 25 | 73 | 343 | 1 | 0 | 0 |
| HEX | 25 | 74 | 344 | 1 | 0 | 0 |
| HEX | 25 | 75 | 345 | 2 | 0 | 0 |
| HEX | 25 | 75 | 346 | 2 | 0 | 0 |
| HEX | 26 | 76 | 347 | 1 | 0 | 0 |
| HEX | 26 | 77 | 348 | 1 | 0 | 0 |
| HEX | 26 | 78 | 349 | 1 | 0 | 0 |
| HEX | 27 | 79 | 350 | 1 | 0 | 0 |
| HEX | 27 | 80 | 351 | 1 | 0 | 0 |

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|---|---|---|---|---|---|---|
| HEX | 27 | 81 | 352 | 2 | 0 | 0 |
| HEX | 27 | 81 | 353 | 2 | 1 | 0 |
| HEX | 27 | 81 | 354 | 2 | 2 | 0 |
| HEX | 28 | 82 | 355 | 1 | 0 | 0 |
| HEX | 28 | 83 | 356 | 1 | 0 | 0 |
| HEX | 28 | 84 | 357 | 1 | 0 | 0 |
| HEX | 29 | 85 | 358 | 1 | 0 | 0 |
| HEX | 29 | 86 | 359 | 1 | 0 | 0 |
| HEX | 9999 | 9999 | 360 | 9999 | 9999 | 1 |
| HEX | 29 | 87 | 361 | 2 | 0 | 0 |
| HEX | 29 | 87 | 362 | 2 | 0 | 0 |
| HEX | 30 | 88 | 363 | 1 | 0 | 0 |
| HEX | 30 | 89 | 364 | 1 | 0 | 0 |
| HEX | 30 | 90 | 365 | 1 | 0 | 0 |
| HEX | 31 | 91 | 366 | 1 | 0 | 0 |
| HEX | 31 | 92 | 367 | 1 | 0 | 0 |
| HEX | 31 | 93 | 368 | 2 | 0 | 0 |
| HEX | 31 | 93 | 369 | 2 | 1 | 0 |
| HEX | 31 | 93 | 370 | 2 | 2 | 0 |
| HEX | 32 | 94 | 371 | 1 | 0 | 0 |
| HEX | 32 | 95 | 372 | 1 | 0 | 0 |
| HEX | 32 | 96 | 373 | 1 | 0 | 0 |
| HEX | 33 | 97 | 374 | 1 | 0 | 0 |
| HEX | 33 | 98 | 375 | 1 | 0 | 0 |
| HEX | 33 | 99 | 376 | 2 | 0 | 0 |
| HEX | 33 | 99 | 377 | 2 | 0 | 0 |
| HEX | 34 | 100 | 378 | 1 | 0 | 0 |
| HEX | 34 | 101 | 379 | 1 | 0 | 0 |
| HEX | 34 | 102 | 380 | 1 | 0 | 0 |
| HEX | 35 | 103 | 381 | 1 | 0 | 0 |
| HEX | 35 | 104 | 382 | 1 | 0 | 0 |
| HEX | 35 | 105 | 383 | 2 | 0 | 0 |
| HEX | 35 | 105 | 384 | 2 | 1 | 0 |
| HEX | 35 | 105 | 385 | 2 | 2 | 0 |
| HEX | 36 | 106 | 386 | 1 | 0 | 0 |
| HEX | 36 | 107 | 387 | 1 | 0 | 0 |
| HEX | 36 | 108 | 388 | 1 | 0 | 0 |
| HEX | 37 | 109 | 389 | 1 | 0 | 0 |
| HEX | 37 | 110 | 390 | 1 | 0 | 0 |
| HEX | 37 | 111 | 391 | 2 | 0 | 0 |
| HEX | 37 | 111 | 392 | 2 | 0 | 0 |
| HEX | 38 | 112 | 393 | 1 | 0 | 0 |
| HEX | 38 | 113 | 394 | 1 | 0 | 0 |
| HEX | 38 | 114 | 395 | 1 | 0 | 0 |
| HEX | 39 | 115 | 396 | 1 | 0 | 0 |
| HEX | 39 | 116 | 397 | 1 | 0 | 0 |
| HEX | 39 | 117 | 398 | 2 | 0 | 0 |
| HEX | 39 | 117 | 399 | 2 | 1 | 0 |
| HEX | 9999 | 9999 | 400 | 9999 | 9999 | 1 |
| HEX | 39 | 117 | 401 | 2 | 2 | 0 |
| HEX | 40 | 118 | 402 | 1 | 0 | 0 |
| HEX | 40 | 119 | 403 | 1 | 0 | 0 |
| HEX | 40 | 120 | 404 | 1 | 0 | 0 |
| HEX | 41 | 121 | 405 | 1 | 0 | 0 |
| HEX | 41 | 122 | 406 | 1 | 0 | 0 |
| HEX | 41 | 123 | 407 | 2 | 0 | 0 |
| HEX | 41 | 123 | 408 | 2 | 0 | 0 |
| HEX | 42 | 124 | 409 | 1 | 0 | 0 |
| HEX | 42 | 125 | 410 | 1 | 0 | 0 |
| HEX | 42 | 126 | 411 | 1 | 0 | 0 |
| HEX | 43 | 127 | 412 | 1 | 0 | 0 |
| HEX | 43 | 128 | 413 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| HEX | 43 | 129 | 414 | 2 | 0 | 0 |
| HEX | 43 | 129 | 415 | 2 | 1 | 0 |
| HEX | 43 | 129 | 416 | 2 | 2 | 0 |
| HEX | 44 | 130 | 417 | 1 | 0 | 0 |
| HEX | 44 | 131 | 418 | 1 | 0 | 0 |
| HEX | 44 | 132 | 419 | 1 | 0 | 0 |
| HEX | 45 | 133 | 420 | 1 | 0 | 0 |
| HEX | 45 | 134 | 421 | 1 | 0 | 0 |
| HEX | 45 | 135 | 422 | 2 | 0 | 0 |
| HEX | 45 | 135 | 423 | 2 | 0 | 0 |
| HEX | 46 | 136 | 424 | 1 | 0 | 0 |
| HEX | 46 | 137 | 425 | 1 | 0 | 0 |
| HEX | 46 | 138 | 426 | 1 | 0 | 0 |
| HEX | 47 | 139 | 427 | 1 | 0 | 0 |
| HEX | 47 | 140 | 428 | 1 | 0 | 0 |
| HEX | 47 | 141 | 429 | 2 | 0 | 0 |
| HEX | 47 | 141 | 430 | 2 | 1 | 0 |
| HEX | 47 | 141 | 431 | 2 | 2 | 0 |
| HEX | 48 | 142 | 432 | 1 | 0 | 0 |
| HEX | 48 | 143 | 433 | 1 | 0 | 0 |
| HEX | 48 | 144 | 434 | 1 | 0 | 0 |
| HEX | 49 | 145 | 435 | 1 | 0 | 0 |
| HEX | 49 | 146 | 436 | 1 | 0 | 0 |
| HEX | 49 | 147 | 437 | 2 | 0 | 0 |
| HEX | 49 | 147 | 438 | 2 | 0 | 0 |
| HEX | 50 | 148 | 439 | 1 | 0 | 0 |
| HEX | 9999 | 9999 | 440 | 9999 | 9999 | 1 |
| HEX | 50 | 149 | 441 | 1 | 0 | 0 |
| HEX | 50 | 150 | 442 | 1 | 0 | 0 |
| HEX | 51 | 151 | 443 | 1 | 0 | 0 |
| HEX | 51 | 152 | 444 | 1 | 0 | 0 |
| HEX | 51 | 153 | 445 | 2 | 0 | 0 |
| HEX | 51 | 153 | 446 | 2 | 1 | 0 |
| HEX | 51 | 153 | 447 | 2 | 2 | 0 |
| **GRAND TOTAL** | | 348 | 447 | 59 | 29 | 11 |

[a] Rotation Panel Design (RP) or centroids of EMAP hexagons (HEX)
[b] Segment identification code
[c] Field number within a segment
[d] Sample code number for analysis laboratories
[e] Second composite sample collected within a field (1:no, 2:yes)
[f] Duplicate sample of second composite sample (0:no, 1: 1 of 2, 2: 2 of 2)
[g] Known blank to test laboratory accuracy (0:no, 1:yes)
[h] Code for known blank

APPENDIX 8

Ecology and Epidemiology

# Response of Two White Clover Clones to Peanut Stunt Virus and Ozone

Allen S. Heagle, Michael R. McLaughlin, Joseph E. Miller, and Ronald L. Joyner

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Cooperative investigations of the USDA-ARS and the North Carolina State University. Funded in part by the North Carolina Agricultural Research Service.

The use of trade names in this publication does not imply endorsement of the products named, nor criticism of similar ones not mentioned, by the North Carolina Agricultural Research Service or the USDA.

We thank Robert Philbeck for construction and maintenance of dispensing and monitoring systems; Fred Mowry for data acquisition software; John Rawlings, Susan Spruill, and Thangam Arumugham for statistical advice and analyses; James Moyer and Lee Campbell for technical advice; and Walter Pursley, Sam Isenhower, Cathryn Gruce, and Scott Karriker for technical assistance.

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## ABSTRACT

Heagle, A. S., McLaughlin, M. R., Miller, J. E., and Joyner, R. L. 1992. Response of two white clover clones to peanut stunt virus and ozone. Phytopathology 82:254-258.

Effects of ozone ($O_3$) and peanut stunt virus (PSV) on two clones of white clover (*Trifolium repens*) were measured in open-top field chambers. An $O_3$-resistant clone (NC-R) and an $O_3$-sensitive clone (NC-S), with and without PSV infection, were exposed to $O_3$ for 12-h day$^{-1}$ for 111 days. The exposures were proportional to ambient $O_3$ and resulted in 12-h day$^{-1}$ mean concentrations of 26, 45, 64, and 76 nL L$^{-1}$ for the 111 days of exposure. Plant shoots were harvested five times to measure effects of $O_3$ and PSV on foliar injury, foliar chlorophyll, and shoot dry weight. Infection by PSV caused foliar chlorosis, which tended to be more severe on NC-S than on NC-R. PSV infection suppressed shoot dry weight accumulation of NC-R by 23% and of NC-S by 18%. $O_3$ also caused foliar chlorosis and suppressed shoot dry weight accumulation, and the severity of the effects increased with increased $O_3$ dose. Seasonal shoot weight of NC-S plants exposed in nonfiltered air chambers to ambient concentrations of $O_3$ (45 nL L$^{-1}$) was 20% less than for NC-S plants in charcoal-filtered air chambers (26 nL L$^{-1}$). Shoot weight of NC-R was not significantly affected by any of the $O_3$ treatments. The clone × $O_3$ interaction was significant for all measures for each harvest except for the first harvest. Although the $O_3$ concentrations remained relatively constant, the differences between NC-S and NC-R shoot weight became greater as the season progressed. There were no significant interactions between $O_3$ and PSV for any of the response measures.

White clover (*Trifolium repens* L.) and tall fescue (*Festuca arundinacea* Schreb.) are commonly grown together in the southeastern United States to provide high quality forage for livestock. However, the clover usually persists for only a few years. Microorganisms, insects, poor management practices, plant competition, poor drought tolerance, and tropospheric ozone ($O_3$) have been suggested as causes for white clover decline (3,5).

Tropospheric $O_3$ causes foliar injury and suppresses yield of many crops (11,16), and white clover is among the most sensitive (2,3,15,21). In a 2-yr field study with 'Tillman' white clover grown with fescue at Raleigh, NC, ambient $O_3$ suppressed shoot weight production of the clover by 22% each year (3). In a subsequent field study with 'Regal' white clover grown with fescue at Raleigh, ambient $O_3$ suppressed shoot weight production of the clover by 8% the first year and by 44% in the second (15,24). Clover plants that survived that study were propagated clonally to determine whether selection for resistance to $O_3$ had occurred. More individuals from the population of plants that survived exposure to high $O_3$ levels were resistant to foliar injury induced by short-term $O_3$ exposure than were individuals from the population that survived exposure to low $O_3$ levels (13). Whether the observed selection for resistance of foliage to injury from short-term (acute) $O_3$ exposures is related to resistance to growth effects caused by long-term (chronic) $O_3$ exposure is not known.

Peanut stunt virus (PSV) is one of the most prevalent viruses of white clover in the southeastern United States (1,20). One field study with two clover clones, propagated vegetatively from PSV-infected plants, showed that PSV caused from 49 to 91% loss in shoot weight accumulation, depending on the year and clone (23). In another field study, in which seedlings were inoculated with PSV before placement in the field, PSV caused a 28% suppression in shoot weight production, and the level of reduction was greater with increased duration of infection (8). Results from growth chamber studies with PSV (10) were similar to those reported for seedlings (8).

Virus infection often causes some protection from $O_3$ injury, and the type and degree of protection depends on the specific host and virus (4,6,7,22,26,27). However, there are exceptions to this generality. $O_3$ caused more injury on tobacco infected with tobacco streak virus than it did on uninfected tobacco (25). Three burley tobacco cultivars infected with tobacco etch virus tended to show less $O_3$-induced growth suppression than uninfected plants, but tobacco vein mottling virus tended to cause the opposite effect (26). For both viruses, the response to $O_3$ was dependent on the cultivar (26). The mechanisms for virus-induced changes in plant response to pollutants are unknown, although virus titer, plant age, and season of the year are important factors. There have been no studies to determine whether clover viruses affect clover response to $O_3$ or vice versa.

This study was done to determine: the differences in growth response to long-term $O_3$ exposure for two clover clones known to be sensitive or resistant to injury from short-term $O_3$ exposure; the relative importance of tropospheric $O_3$ and PSV in causing growth decline of white clover; and whether PSV infection affects clover response to $O_3$ or vice versa.

## MATERIALS AND METHODS

White clover plants that survived a 2-yr field study to determine effects of chronic $O_3$ exposure (15,24) were propagated and screened for relative sensitivity to $O_3$. One clone survived 2 yr of exposure to high $O_3$ levels and subsequently was shown to be resistant to $O_3$, whereas the other had been exposed to low levels of $O_3$ and was very sensitive (13). The resistant clone (NC-

R) and the sensitive clone (NC-S) were subsequently freed of viruses by shoot-tip meristem culture (13).

On 6 February 1989, cuttings of each clone were placed in pots containing 0.22 L of a 2:1:1 mixture of sandy loam topsoil, sand, Metro Mix 220 (W. R. Grace Co. Cambridge, MA) in a greenhouse. Half of the plants (84 of each clone) were mechanically inoculated with PSV on each of 3 days (13, 14, and 15 March 1989). On each date, upper leaf surfaces were rubbed with expressed sap from PSV-infected white clover leaves in 0.03 M sodium phosphate buffer at pH 7.4, containing 0.02 M 2-mercaptoethanol and 600 mesh Carborundum. On 23 March, all plants were individually transplanted to pots containing 14 L of the 2:1:1 medium and were next inoculated with *Rhizobium*. Plants were cut to a height of 5 cm on 24 April.

The experimental design was a randomized complete block with four blocks of four $O_3$ treatments in open-top chambers (12) with subplots of two clones (NC-S and NC-R) and two virus treatments (plants with and without PSV inoculation). Each of the 16 chambers contained 16 pots (four pots each of the NC-S and NC-R clones, with and without inoculation with PSV). Plants were transferred to open-top field chambers on 3 May and were watered as needed to prevent moisture stress throughout the season. To decrease the chances of spreading PSV to noninoculated plants, all inoculated plants were randomly assigned to one side of each chamber (east or west). This arrangement allowed a minimum of 30 cm between inoculated and noninoculated plants. The two clones were arranged in two randomized 2 × 2 latin squares on each side of the chamber.

An enzyme-linked immunosorbent assay (ELISA) (19) done on 22 May for all PSV-inoculated plants showed that 60 of the 64 NC-S plants were infected, but that only 33 of the 64 NC-R plants were infected. However, there were at least two NC-R plants that tested positive for PSV in all but three chambers and four NC-S plants with PSV in all but four chambers. Inoculated plants that tested negative for PSV were not included in any data analyses or interpretation of results but were retained to maintain plot uniformity.

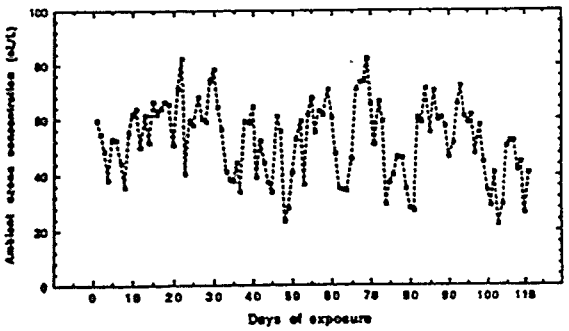


Fig. 1. Daily 12-h per day (0800–2000 h EST) ozone ($O_3$) concentrations in ambient air 8 km south of Raleigh, NC, during studies to measure effects of $O_3$ and peanut stunt virus on two ladino clover clones. The figure shows ambient $O_3$ concentrations for the 111 days from 4 May to 23 August 1989.

$O_3$ dispensing and monitoring techniques have been described previously (14). The $O_3$ treatments, which began on 4 May, were charcoal-filtered air, nonfiltered air, and two nonfiltered air treatments to which $O_3$ was added for 12-h $day^{-1}$ (0800–2000 h EST) in amounts proportional to ambient $O_3$ concentrations. The seasonal (4 May to 23 August) 12-h $day^{-1}$ mean $O_3$ concentrations in ambient air and in the charcoal-filtered air, nonfiltered air, and two $O_3$-added treatments were 51, 26, 45, 64, and 76 nL $L^{-1}$, respectively. The chamber fans were turned off from 2100 to 0500 h EST daily.

Plants were cut to a height of approximately 7 cm above the soil level on five dates during the experiment: 11 May; 5–6 June; 28–29 June; 25–26 July; and 23–24 August. Stolons growing outside of the perimeter of each pot were also cut. At each harvest, the shoots (leaves, petioles and/or stolons and flowers) were placed in paper bags, dried for 2 days at 55 C, and weighed.

Estimates of foliar injury and foliar chlorophyll analyses were performed one day before the second, fourth, and fifth harvests using five adjacent leaves on one stolon, starting with the youngest fully expanded leaf. Visible foliar injury was estimated for each leaf as the percentage of chlorosis and necrosis in 5% increments (0–100%). The same leaves were used for chlorophyll analyses as described by Knudsen et al (18). Leaves were placed in approximately 70 ml of ethyl alcohol (one brown glass container per five-leaf sample) and placed in the dark. After 3 days, the volume of alcohol for each container was increased to 100 ml, and the amounts of chlorophyll a and b were measured spectrophotometrically.

Starting on 19 May, all plants were sprayed at 2- to 3-wk intervals with Capture (bifenthrin), 3.2 EC, 3.1 mL $L^{-1}$ to prevent infestation of aphids and decrease the potential for spread of viruses. ELISA tests were done on 7 August to determine whether plants not inoculated in March had become infected with PSV, alfalfa mosaic virus, clover yellow vein virus, red clover vein mosaic virus, or white clover mosaic virus. The results were negative for all but five plants: two NC-R and two NC-S plants (three separate plots) were positive for PSV, and one NC-R plant was positive for clover yellow vein virus. Therefore, data from these plants were discarded.

Data from inoculated plants that tested negative for PSV on 22 May were not used in statistical analyses, so the latin square design was incomplete. Therefore, the design was reduced to a split-split plot with unequal samples in the subplots. Analyses of variance were done for shoot weight, chlorophyll content, and foliar injury for each harvest separately, and for total seasonal shoot weight using SAS software (SAS Institute, Cary, NC). Mild heterogeneity of variance was found for the last two harvests, but data transformations were not considered to be advantageous.

TABLE 1. Mean squares from analyses of variance for effects of ozone on shoot (leaves, petioles, and/or stolons and flowers) dry weight (grams per pot), total chlorophyll (μg/ml), and foliar injury (mean percentage per leaf) for two white clover clones, with and without infection by peanut stunt virus[a]

| | | Harvest 1 | Harvest 2 | | | Harvest 3 | Harvest 4 | | | Harvest 5 | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | df | Shoot dry wt | Shoot dry wt | Total chlorophyll | Foliar injury[b] | Shoot dry wt | Shoot dry wt | Total chlorophyll | Foliar injury | Shoot dry wt | Total chlorophyll | Foliar injury | Shoot dry wt |
| Block (B) | 3 | 47* | 787** | 215 | 7 | 280* | 50 | 1 | 14 | 52 | 77 | 7 | 1,650* |
| Ozone (O) | 3 | 8 | 599** | 188 | 117** | 2,575** | 6,021** | 739** | 438* | 5,557** | 693** | 357** | 50,462** |
| Virus (V) | 1 | 206** | 2,598** | 197** | 59** | 4,919** | 1,719** | 78** | 39** | 3,225** | 188** | 43** | 54,111** |
| V × O | 3 | 3 | 40 | 61 | 1 | 74 | 162 | 37 | 0 | 248 | 76 | 10 | 985 |
| Clone (C) | 1 | 184** | 4,081** | 486** | 194** | 6,917** | 20,132** | 403** | 204** | 11,466** | 229** | 185** | 170,344** |
| C × O | 3 | 4 | 1,058** | 378** | 84** | 3,035** | 3,929** | 230** | 108** | 1,450** | 211** | 50** | 35,160** |
| C × V | 1 | 16** | 388** | 75* | 0 | 195** | 94* | 19 | 1 | 1,243** | 0 | 3 | 6,650** |
| C × O × V | 3 | 2 | 32 | 10 | 2 | 88 | 120 | 35 | 5 | 84 | 15 | 4 | 683 |

[a] * and ** = significant at the 0.05 and 0.01 level of confidence, respectively.
[b] Values for foliar injury have been multiplied by 0.001.

Regression analyses were done using SAS or Cricket Software (Cricket Software, Malvern, PA) with shoot weight and chlorophyll content as the dependent variables and mean 12-h day$^{-1}$ $O_3$ concentrations (for individual growth periods and for the total season) as the independent variable.

## RESULTS

The daily $O_3$ fluctuations (Fig. 1) and seasonal mean $O_3$ concentrations in ambient air during this experiment were similar to previous seasons at the site (15). The weather during the study was somewhat cooler and wetter than normal with daily mean maximum temperatures of 20, 28, 30, 31, and 30 C and rainfall of 6, 4, 17, 12, and 19 cm for growth periods 1-5, respectively.

**Virus effects.** Infection by PSV caused approximately 5-10% foliar injury (chlorosis) on both the $O_3$-sensitive clone (NC-S) and $O_3$-resistant clone (NC-R) at each harvest (Tables 1,2). The response of chlorophylls a and b to PSV and the $O_3$ treatments were similar, so chlorophyll responses will be presented in terms of total chlorophyll. Total chlorophyll content of PSV-infected NC-S plants (mean across all treatments) was 21 and 23% less than for uninfected NC-S plants for harvests 2 and 4, respectively (Table 2). The comparable numbers for NC-R were 5 and 8%, respectively. The clone × PSV interaction for chlorophyll was significant at harvest 2 (Table 1), but the PSV effect was similar for both clones at harvest 5.

Fewer NC-R than NC-S plants became infected by PSV from mechanical inoculation, and PSV generally caused smaller decreases of NC-R chlorophyll than of NC-S chlorophyll. The clone × PSV interaction was significant at harvest 2 (Table 1). However, NC-R was more sensitive to growth effects of PSV than was NC-S. For all chamber treatments combined, infection by PSV suppressed seasonal shoot weight production of NC-R by 23% and of NC-S by 18% (Table 3; Fig. 2), and the clone × PSV interaction for shoot weight was significant at each harvest (Table 1). There were no significant PSV × $O_3$ or three-way interactions for shoot weight. The differences in shoot weight response of the two clones to PSV at the different $O_3$ levels at the individual harvests (Table 3) were similar to those shown for seasonal shoot weight production (Table 3; Fig. 2).

**$O_3$ effects.** $O_3$ exposure caused foliar injury (chlorosis and necrosis) and decreased foliar chlorophyll content (Tables 1,2). The effects were significant except for chlorophyll at harvest 2. The effects of $O_3$ were much greater on the $O_3$-sensitive NC-S than on the $O_3$-resistant NC-R (Table 2) and caused the significant clone × $O_3$ interaction for all harvests for both measures (Table 1).

Except for harvest 1 (after 7 days of $O_3$ treatment), the effect of $O_3$ on shoot weight was significant at all harvests (Table 1). $O_3$ suppressed seasonal shoot production of NC-S more than that of NC-R (Table 3; Fig. 2), and the $O_3$ × clone interaction was significant at all harvests. The difference between shoot weight of plants grown in charcoal-filtered air and shoot weight of plants grown at higher $O_3$ concentrations increased as the season progressed. For example, shoot weight of NC-S in the nonfiltered air treatment (45 nL L$^{-1}$ of $O_3$) was 88, 88, 79, and 56% of that in the charcoal-filtered air treatment (26 nL L$^{-1}$ of $O_3$) for harvests 2, 3, 4, and 5, respectively. Likewise, shoot weight of NC-R in the highest $O_3$ treatment (76 nL L$^{-1}$) was 104, 102, 95, and 77% of that at 26 nL L$^{-1}$ for harvests 2, 3, 4, and 5, respectively. The standardized slopes (standardized to a maximum of 1 by dividing the slope of each regression model by its intercept) of the shoot weight response increased for NC-S across all harvests and increased for NC-R between harvests 4 and 5 (Table 3). The same trends for increased response with successive exposure occurred for PSV-infected plants of both clones, and there were no PSV × $O_3$ interactions.

## DISCUSSION

The present study showed that NC-S, which was more sensitive to foliar injury from acute $O_3$ exposure than NC-R, was also more sensitive than NC-R to growth effects caused by chronic $O_3$ exposure. These results agree with previous studies showing the relationship between $O_3$ doses and forage production of white clover (3,15,21). The present study also showed that the amount of yield loss caused by PSV and ambient $O_3$ was similar for NC-S and corroborated a previous report of differences in sensitivity to PSV between clones of white clover (23). Because cultivars of white clover are extremely heterozygous, cultivars probably contain genotypes with a wide range in sensitivity to both stresses, so the relative importance of $O_3$ and PSV for a given cultivar will presumably depend on the degree of sensitivity to both stresses among the genotypes.

The results suggest that chronic exposure to $O_3$ caused plants to become more sensitive to effects of subsequent exposure. However, the differences in response could have been caused by other factors, including the influence of weather patterns or physiological effects related to onset of flowering. We can only surmise as to the relative importance of these factors, because none was specifically studied. There were no obvious relationships between temperature or rainfall and the change in response to $O_3$; temperatures were relatively uniform, and plants were irrigated to prevent moisture stress. Flowering of the two clones began at different times (near the beginning of growth period 1 for NC-R and near

TABLE 2. Effects of chronic exposure to different levels of ozone on foliar injury and chlorophyll content of an ozone-resistant (NC-R) and an ozone sensitive (NC-S) white clover clone with and without infection by peanut stunt virus (V)

| Growth period[b] | Number of exposure days | Ozone treatment[c] | 12-h mean ozone concentration (nL L$^{-1}$) | Percentage of foliar injury[a] | | | | Total chlorophyll (μg/ml)[a] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NC-R | NC-S | NC-RV | NC-SV | NC-R | NC-S | NC-RV | NC-SV |
| 2 | 25 | CF | 32 | 1 | 4 | 10 | 12 | 29.1 | 29.7 | 30.4 | 25.9 |
| | | NF | 56 | 2 | 18 | 14 | 24 | 29.1 | 31.7 | 29.6 | 26.9 |
| | | NF-1 | 78 | 1 | 32 | 16 | 44 | 32.7 | 26.1 | 29.1 | 20.9 |
| | | NF-2 | 97 | 5 | 41 | 14 | 60 | 33.0 | 23.1 | 28.4 | 14.2 |
| 4 | 27 | CF | 25 | 0 | 1 | 17 | 5 | 19.5 | 22.8 | 18.4 | 17.1 |
| | | NF | 43 | 2 | 31 | 10 | 38 | 20.8 | 16.7 | 22.7 | 15.4 |
| | | NF-1 | 63 | 24 | 50 | 33 | 64 | 18.0 | 11.9 | 16.2 | 7.6 |
| | | NF-2 | 72 | 24 | 65 | 33 | 74 | 18.0 | 7.9 | 13.0 | 5.5 |
| 5 | 29 | CF | 23 | 2 | 5 | 19 | 22 | 20.6 | 23.3 | 14.8 | 17.9 |
| | | NF | 43 | 7 | 41 | 27 | 48 | 18.5 | 15.0 | 13.9 | 12.1 |
| | | NF-1 | 63 | 29 | 56 | 35 | 65 | 13.8 | 8.1 | 13.5 | 6.7 |
| | | NF-2 | 73 | 30 | 66 | 46 | 64 | 16.2 | 6.9 | 10.2 | 5.9 |

[a]Each value is the mean injury per leaf or mean chlorophyll per five leaves for 20 leaves (five leaves on one plant in four blocks).
[b]Growth period 2 = from 11 May to 4 June; growth period 4 = from 28 June to 24 July; growth period 5 = from 25 July to 22 August.
[c]Plants were exposed for 12 h per day in open-top field chambers to charcoal-filtered air (CF), nonfiltered air (NF), or to NF with different proportions of ambient ozone added.

TABLE 3 Dry weight of shoots (leaves, petioles, and or stolons and flowers) of an ozone-resistant (NC-R) and an ozone-sensitive (NC-S) clone of white clover with and without infection by peanut stunt virus (V) after exposure to different levels of ozone[a]

| Growth period | Days of growth | Ozone treatment[a] | 12-h mean ozone concentration (nL $L^{-1}$) | Ozone dose (nL $L^{-1}$ h 100) | Shoot dry weight per plant (g)[b] NC-R | NC-S | NC-RV | NC-SV |
|---|---|---|---|---|---|---|---|---|
| 1 | 7 | CF | 31 | 26 | 10.0 | 7.9 | 7.3 | 6.4 |
| | | NF | 48 | 40 | 10.1 | 7.3 | 7.2 | 5.7 |
| | | NF-1 | 57 | 48 | 10.5 | 7.5 | 7.8 | 6.1 |
| | | NF-2 | 65 | 55 | 10.1 | 7.7 | 8.0 | 6.4 |
| 2 | 25 | CF | 32 | 96 | 35.4 | 28.9 | 26.3 | 25.7 |
| | | NF | 56 | 168 | 36.8 | 25.5 | 26.2 | 21.8 |
| | | NF-1 | 78 | 234 | 37.1 | 22.9 | 26.0 | 17.1 |
| | | NF-2 | 97 | 291 | 36.9 | 19.6 | 28.1 | 14.0 |
| | | | | Standardized slope[c] | +0.65 | −4.19 | +0.90 | −5.78 |
| 3 | 23 | CF | 22 | 61 | 59.9 | 56.3 | 47.9 | 45.9 |
| | | NF | 38 | 105 | 59.1 | 49.3 | 46.5 | 41.9 |
| | | NF-1 | 55 | 152 | 57.7 | 40.7 | 49.5 | 33.1 |
| | | NF-2 | 65 | 179 | 61.2 | 35.5 | 47.7 | 27.8 |
| | | | | Standardized slope | +0.15 | −7.21 | +0.43 | −7.59 |
| 4 | 27 | CF | 25 | 81 | 50.4 | 41.9 | 44.4 | 34.9 |
| | | NF | 43 | 139 | 50.5 | 33.4 | 42.0 | 27.0 |
| | | NF-1 | 63 | 204 | 48.7 | 18.7 | 45.0 | 15.9 |
| | | NF-2 | 72 | 233 | 48.1 | 15.0 | 38.4 | 12.1 |
| | | | | Standardized slope | −1.02 | −10.37 | −1.65 | −10.40 |
| 5 | 29 | CF | 23 | 80 | 38.7 | 28.9 | 23.9 | 19.6 |
| | | NF | 43 | 150 | 38.3 | 16.3 | 23.8 | 13.6 |
| | | NF-1 | 63 | 219 | 34.8 | 7.6 | 23.0 | 8.1 |
| | | NF-2 | 73 | 254 | 29.9 | 5.0 | 16.9 | 3.5 |
| | | | | Standardized slope | −3.78 | −12.42 | −4.12 | −11.58 |
| 1-5 | 111 | CF | 26 | 344 | 194 | 164 | 150 | 133 |
| | | NF | 45 | 602 | 195 | 132 | 146 | 110 |
| | | NF-1 | 64 | 857 | 189 | 97 | 151 | 80 |
| | | NF-2 | 76 | 1,012 | 186 | 83 | 139 | 64 |
| | | | | Standardized slope | −0.86 | −8.82 | −0.96 | −8.21 |

[a] Plants were exposed for 12-h $day^{-1}$ in open-top field chambers to charcoal-filtered air (CF), nonfiltered air (NF), and to NF with different proportions of ambient $O_3$ added (NF-1 and NF-2). Growth periods 1 = 4–10 May; 2 = 11 May–4 June; 3 = 5–27 June; 4 = 28 June–24 July; 5 = 25 July–22 August.

[b] Each value for NC-R and NC-S is the mean of 16 plants (four pots, four blocks [chambers]) except for two NC-S and three NC-R plants that were discarded because of virus infection; each value for NC-RV is the mean of six to nine plants (one to three pots, four blocks); each value for NC-SV is the mean of 13–16 plants (two to four pots, four blocks).

[c] Defined as the slope of the linear response model adjusted by dividing the slope by the intercept. Models were estimated using Cricket Software with the independent variable as $O_3$ in $\mu L\ L^{-1}$.

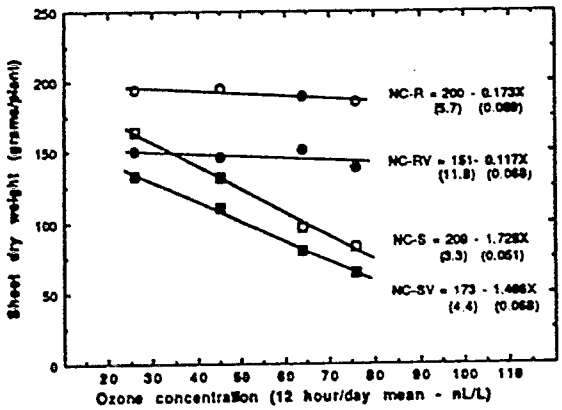


Fig. 2. Effects of chronic exposure to ozone ($O_3$) on seasonal shoot dry weight production by two clover clones (NC-R and NC-S) with and without infection by the peanut stunt virus (V). The regression models show the relationships between seasonal production of shoot dry weight per plant (grams) and seasonal 12-h per day $O_3$ concentration (X) in nL $L^{-1}$. Standard errors are shown in parenthesis. The models for NC-S and NC-SV were statistically significant (slope different from 0 as shown by an $F$ test), but the models for NC-R and NC-RV were not significant.

the end of growth period 3 for NC-S). Both clones produced flowers until the end of the experiment. The greatest changes in response to $O_3$ occurred between growth periods 3 and 4 for both clones. Thus, the onset of flowering occurred near the time of a large change in $O_3$ response for NC-S but not for NC-R. The most plausible explanation for the change in response to a given $O_3$ dose is that the observed decrease in foliar chlorophyll concentration (Table 2) was accompanied by a decrease in photosynthesis and, therefore, decreased energy reserves in stolons and roots. $O_3$ has been shown to decrease white clover root-shoot ratios (20) and to decrease levels of starches in white clover roots (23). A gradual decrease in energy reserves probably would be accompanied by decreased capacity for detoxification or repair.

Because the effects of a given $O_3$ dose increased with successive growth periods, a cumulative $O_3$ dose metric would probably be more appropriate as the independent variable in regression analyses than a growth period mean. A cumulative $O_3$ dose, differentially weighted for successive growth periods, might be suitable. Further research is required to clarify the role of weather conditions and the level of cumulative effects for each clone.

The effect of PSV on shoot growth was variable over the season. For NC-R in charcoal-filtered air, PSV decreased shoot weight by 27, 26, 20, 12, and 38%, respectively, for the five consecutive harvests. The comparable values for NC-S were 19, 12, 18, 17, and 32%. No gradual trend for increased effects of PSV occurred with increased duration of infection. The large increase in PSV-

induced loss for both clones at harvest 5 may have been due to increased duration of infection combined with our practice of harvesting stolons that grew outside of the pots. Infection with PSV is known to reduce the root system in white clover (10), and harvesting stolons that grew outside of the pots decreased the establishment of secondary root systems.

The response of NC-S and NC-R, expressed as a ratio, could be a useful indicator of ambient $O_3$ levels and of the $O_3$ effects on other crop species. The usefulness for indicating ambient $O_3$ will depend on how much the two clones vary in response to other factors that affect growth. Measurements of shoot weight production indicated little or no effect of differences in weather conditions on the relative growth of NC-S and NC-R in charcoal-filtered air; the percentage of the total seasonal shoot weight produced during each growth period was almost identical for both clones. Further development of these clones as an $O_3$ indicator will require more data on their relative response to variation in weather conditions, edaphic factors, biotic diseases, as well as other atmospheric factors such as carbon dioxide and sulfur dioxide. Using the clover system to indicate the effects of $O_3$ on other crops will require knowledge of how given factors affect clover response to $O_3$ relative to how the same factors affect response of other crops to $O_3$. In other words, this will require information on how the clover clones and other crops respond to $O_3$ over a wide range of conditions.

Although PSV-resistant germ plasms that are adapted to the southeastern United States (9,17) are available, their reaction to $O_3$ is not known. Thus, characterization of the overall level of resistance to $O_3$ and PSV in white clover strains might be worthwhile as part of the development of strains with improved persistence in the Southeast.

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