The National Resources Inventory and its Role in U.S. Agriculture

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ABSTRACT: This paper discusses various aspects of the National Resources Inventory program, which is conducted by the Natural Resources Conservation Service, an agency of the United States Department of Agriculture, in cooperation with the Iowa State University Statistical Laboratory. The Natural Resources Conservation Service, formerly the Soil Conservation Service, has been collecting natural resources data since the 1930s. The current inventory is a longitudinal survey of soil, water and related resources designed to assess condition and trends every five years on the non-federal lands of the United States. An historical overview of this multi-resource inventory is provided. Sample design and data collection are described. Data analysis techniques and modeling are discussed in relation to agri-environmental issues and policy. The National Resources Inventory has evolved over the decades as resource issues have changed; it will continue to evolve as part of an ongoing effort to better assess soil conservation, natural resources health, and other environmental issues.

1. Introduction

The Natural Resources Conservation Service (NRCS) is an agency of the United States Department of Agriculture (USDA). Formerly known as the Soil Conservation Service, its mission is "to provide leadership in a partnership effort to help people conserve, improve, and sustain our natural resources and the environment." The Soil Conservation Service was established as part of the Soil Conservation Act of 1935. Hugh Hammond Bennett, the agency founder and first chief, was able to convince the U.S. Congress that soil erosion was a national menace and that a permanent agency within USDA was needed to call landowners' attention to their land stewardship opportunities and responsibilities. This legislation was based, in part, upon results from the *1934 National Erosion Reconnaissance Survey*, which was the first formal study of erosion conducted in the U.S.

Knowledge about the Nation's natural resources is critical for agriculture and for the well-being of the Nation's people. As part of NRCS's mission, it collects large quantities of data, both at the field level and at a larger scale. Much data is collected at the field and farm (or ranch) level by thousands of NRCS employees highly skilled in many scientific and technical specialties, including soil science, soil conservation, agronomy, biology, agroecology, range conservation, forestry, engineering, geology, hydrology, cultural resources, and economics. These specialists provide technical assistance to farmers and ranchers in development of conservation systems uniquely suited to their land and their individual ways of doing business. Assistance is also provided to rural and urban communities to reduce erosion, conserve and protect water, and solve other resource problems.

NRCS is also mandated (through the Rural Development Act of 1972, the Soil and Water Resources Conservation Act of 1977, and other supporting legislation) to assess the status, condition, and trends of soil, water and related resources on the Nation's non-Federal lands at intervals not exceeding 5 years. To help accomplish this assessment, the National Resources Inventory (NRI) program has been developed. The NRI program was developed to augment the agency's soil survey program, which has developed extensive detailed soils maps and extensive soil interpretations data bases. This wealth of soils information serves as an invaluable base for NRI data collection and assessments and helps make the NRI a unique inventory.

This paper presents information on past and present resource inventory activities of NRCS. Resource inventories have changed significantly over the decades; this is mostly because natural resource issues that concern the public change over time — soil erosion has been a concern ever since the Dust Bowls of the 1930s; preservation of prime farmland and clean water became issues in the 1960s; concern over wetlands, wildlife habitat, and environmental affects of agriculture have become issues more recently. Inventories have also changed because much has been learned from previous inventories, and because of technological and scientific advancements in fields such as statistics, soil science, agronomy, computer and data base technology, and simulation modeling.

Increased interest in environmental health has led to an increased demand for credible information on the Nation's natural resources. Long-standing inventory and monitoring programs have not been providing relevant data to enable effective natural resource and environmental assessment. This is partly because the programs were designed for other purposes, but the major problem is the lack of functional resource assessment protocols and tools. New federal monitoring activities have been proposed, and activities to develop assessment protocols and incorporate them into agency activities are in progress. These assessment procedures will need to be relevant at many scales, including a national inventory to affect national policy and enterprise level to guide land owners and operators. It is likely that soil quality or health will be the cornerstone of these assessment tools, but other facets of the ecosystem are also very relevant [Goebel, Mausbach and Karlen 1997].

2. Historical Perspectives

2.1 Overview

The National Resources Inventory (NRI) is a longitudinal survey that has been designed to assess conditions and trends of soil, water and related resources on non-Federal lands in the United States. It is conducted by NRCS, in cooperation with the Iowa State University Statistical Laboratory. The purpose of the NRI is to provide support for agricultural and environmental policy development and program implementation.

2.2 Reconnaissance Studies in the 1930s and 1940s

Collection of natural resources data started in the 1930s, when there was concern about soil erosion that was being caused by several years of extremely droughty conditions, land management practices that were not attempting to protect the soils resource base, and the effects of soil erosion on agricultural production. Data collection efforts were initially based on reconnaissance methods and the gathering of information from a variety of sources. The *1934 National Erosion Reconnaissance Survey* led to passage of the Soil Conservation Act of 1935, which established the Soil Conservation Service as an agency of the USDA. Existing resource data were assembled and analyzed starting in 1942 to provide a foundation for developing programs and setting priorities for conservation activities throughout the Nation [USDA 1945]. This study became known as the *1945 Conservation Needs Inventory*.

2.3 Survey Sampling Methodology Introduced in the 1950s and 1960s

In 1956, the Soil Conservation Service was assigned responsibility to lead a cooperative endeavor of eight Federal agricultural agencies to develop estimates of the magnitude and urgency of the various conservation measures needed to maintain and improve the country's productive capacity [USDA 1962]. This study was called the *1958 National Inventory of Soil and Water Conservation Needs*, and is sometimes called the *1958 Conservation Needs Inventory (CNI)*. A probability sampling approach using geographical stratification was developed, and samples were selected by Statistical Laboratories at Iowa State and Cornell Universities. Sampling units were nominally square area segments ranging in size from 40 to 640 acres. Data collection consisted of constructing a segment map outlining soil type and land use; acreage measurements made from the maps were expanded and adjusted to match county inventory acreages. Total acres in the population of interest were set by County Inventory Committees using Census of Agriculture land area figures as base acreages. Acres of Federal land, water areas, and urban and built-up areas were subtracted from Census of Agriculture land areas to obtain the surface area in the study population; this acreage figure is called the "county base acreage." After estimates for 1958 were finalized, the results were used by the County Inventory Committees to predict 1975 land use and conservation treatment needs.

The *National Inventory of Soil and Water Conservation Needs, 1967* was conducted primarily to update the 1958 data. To facilitate data collection and processing while reducing field costs, a two-stage sample design was implemented. Except for minor exceptions, the 1958 CNI sample segments were the primary sampling units (PSUs) and points selected within a PSU were the second-stage units. About 38 points were selected in a typical 160 acre PSU using a 2-dimensional systematic pattern. Randomization was incorporated into the point selection process through the start point and orientation. Data collection entailed determining land use and soil type for each sample point, and identifying conservation treatment needs for points classified as cropland, pastureland or rangeland. An expansion factor, or sampling weight, was developed for each point, and an easy-to-use tabulation data set was produced. Weights were controlled so that they summed to 1958 "county base acreages" updated to 1967. Differential sampling rates were used in some large counties and base acres were established for the subdivisions of the county associated with the different rates. It was possible to estimate changes in cropland and other land uses between 1958 and 1967. However, because 1958 land use was not identified for the 1967 sample points, the specific dynamics of change (e.g., how much urban growth occurred on prime farmland) were not directly estimable.

The Potential Cropland Study of 1975 was conducted to determine the quantity, locations, and characteristics of lands that could be easily converted from noncropland to cropland uses. This study was motivated by increasing worldwide demands for agricultural products. A national level sample was easily obtained by selecting a subset of the 1967 CNI sample points. This subsample was developed by first selecting a stratified sample of 506 counties, selecting 5,300 PSUs within these counties, and then selecting every fourth point. Data collected for each sample point included land use for 1975, factors affecting likely conversion to cropland (if not presently cropped), a subjective rating of potential conversion to cropland, and designation of prime farmland points. Soil type and 1967 land use were available from the 1967 CNI.

2.4 Initiation of the National Resources Inventory Program

Demands for up-to-date information and for additional items related to soil and water resources led to development of the *1977 National Resources Inventory*. New data elements included water and wind erosion, conservation practices, incidence of wetlands, and flooding propensity. A subsample of 70,000 of the 1958 CNI PSUs was used, but a new set of sample points was selected. In a typical 160 acre PSU, three points were selected. Some data elements were collected for the entire PSU, while other data items were collected at each sample point. The 1977 NRI was originally called the *SCS Erosion Inventory* because, for the first time, there was a scientific collection of national quantitative erosion data based upon the Universal Soil Loss Equation and the Wind Erosion Equation. A second phase was conducted in 1978 and 1979 to study erosion of stream banks, construction areas and roadsides. The 1977 NRI introduced a number of new methodologies and is considered the starting point for the current NRI program.

In 1982, the NRI sample size and scope were significantly expanded in response to user needs; this included an increased demand for data emphasizing environmental and ecological concerns. Additional data were collected on soils, irrigation practices, wetlands, windbreaks, riparian vegetation, wildlife habitat diversity, critical eroding areas, and many facets of vegetative cover. The base sample of 321,000 PSUs included all 70,000 PSUs used for the 1977 NRI, although new samples were selected for the 13 northeastern states; carry-over samples for the northeast were used for calibration and quality assurance. An additional 44,000 PSUs were selected and inventoried in 20 states to aid in special local studies. Many far-reaching decisions were based upon the 1982 NRI data because of its comprehensiveness [Goebel and George 1998]; for example, the data were used extensively to formulate conservation provisions of the Food Security Act of 1985 and to analyze regional economic impacts. Because land use definitions and erosion estimation protocols were significantly different for the 1977 and 1982 NRIs, the 1982 NRI now plays a crucial role as the initial time point for the monitoring conducted in more recent inventories.

The scope and size of the 1987 NRI were reduced because of staffing and funding constraints. The sample size of 108,000 PSUs included 3,000 PSUs that were not part of the 1982 NRI. The new PSUs were added in 100 counties where analysis showed augmentation was needed; the carry-over PSUs were selected using a post-stratification subsampling procedure based upon urbanization, wetland conversions, and erodibility as evidenced in the 1982 NRI. Data collection protocols, quality assurance, estimation techniques, and data base construction were all designed to ensure that the 1987 NRI provided meaningful and legitimate trending information.

The size and scope of the 1992 NRI were comparable to those of the 1982 NRI. There was a need to have sufficient data to track progress relative to erosion reduction, wetland preservation, and other conservation priorities established during the 1980s, as well as to analyze other natural resource issues such as water quality and the consequences of urban growth on prime and other farmlands. Some data elements collected for the 1982 and/or 1987 NRI were dropped for 1992, and a few new items were added; however, data elements, definitions, and protocols were kept as similar as possible because the main objective of the 1992 NRI was to develop a time series data base for the years 1982, 1987, and 1992 [Kellogg, TeSelle and Goebel 1994, USDA 1994]. The 1992 NRI contained 300,000 PSUs and 800,000 sample points; included are all PSUs that were included in the 1987 NRI plus 6,000 new PSUs that were added to increase sample sizes in specific areas. For those sample units included in the 1982 and 1992 NRI but not sampled in 1987, data were collected retrospectively using photointerpretation and remote sensing materials, to the extent possible. Imputation procedures were used to complete the 1987 data. The statistical estimation procedures were quite complicated because this and other imputation was employed, the data set contained three points in time, and there were numerous "control" figures to be incorporated. Many efforts were made to enhance or create linkages to other data bases; this included development of transparent linkages to the agency's soil characteristics and interpretations data base, and numerous geospatial linkages through geographic information systems.

Data are currently being collected for the 1997 NRI for the same sample sites as were used for the 1992 NRI. A primary focus of this latest NRI is to enhance the trending data base established from the 1992 NRI efforts, but there have been slight modifications to the list of data elements. Also, many operational features have been modified because of agency reorganization and the need for better cost-effectiveness. Concurrently, there have been special inventories conducted during 1995, 1996 and

1997; these are discussed briefly in Section 3.3 of this paper. Forthcoming changes in the NRI program are briefly discussed in Section 5.

3. Current Survey Procedures

3.1 Overview

The objectives of NRCS resource inventories have expanded over time, as the focus of agricultural policy has moved toward a balance between short-term production goals, long-term capabilities, and environmental quality. Statistical techniques and data collection protocols have evolved as inventory goals have become broader and more sophisticated.

3.2 NRI Sample Design

The national sample is a stratified two-stage unequal probability area sample that can be modified for specific national survey objectives and used as a frame for special studies. Stratification was developed county by county, utilizing the grid of sections and townships defined by the Public Land Survey (PLS) system, where possible; a section is a 1-mile square segment of land, and a township is a 6-mile square area consisting of 36 sections. Each township was subdivided into three 2-mile by 6-mile strata for sampling purposes. (For counties not covered by the PLS system, strata were developed either by: (a) utilizing latitude and longitude, (b) utilizing the Universal Transverse Mercator grid system, or (c) superimposing lines analogous to townships and sections over a county highway map.) Two-stage area samples were selected within each stratum. The first stage sample unit, or primary sampling unit (PSU), was an area of land; at the second stage of sampling, one or more sample points were selected within each sample PSU for observation. Most PSUs corresponded to quarter-sections and were half-mile squares; three sample points were selected within most PSUs. Sampling rates varied across strata, typically being between 2 percent and 6 percent. There are instances throughout the U.S. where components of the sample design deviate from these standard rules. Nusser and Goebel [1997], Goebel and Baker [1987], and Goebel, Reiser and Hickman [1985] provide more details on the specifics of the sampling design, and on historical perspectives.

Experience has shown that it is necessary to return to specific sample points that were in previous inventories in order to obtain needed data on the dynamics of change in land use and various natural resource parameters. The national framework sample has consisted of approximately 300,000 PSUs and 800,000 sample points for the 1992 and 1997 National Resources Inventories; almost all of these were also part of the 1982 NRI.

3.3 Data Collection

The primary survey is currently conducted every five years, but there has also been a series of special inventories that have utilized the national sample as a frame for a special topic study. Some of these were conducted as part of the comprehensive national survey and several as an independent study conducted during an interim year. The first was the *1975 Potential Cropland Study*, which was designed to determine the potential for converting land in other uses to cropland in order to meet increasing demands for agricultural products, as well as to study problems related to developing these lands for crop production and the effects of urban development on some of the Nation's best cropland. In the early 1990s, this technique was used for special studies designed to estimate changes in wetland status, to investigate pesticide usage in relation to agriculture practices and water quality, to assess rangeland conditions and trends, and to study conservation tillage practices. The most recent interim year studies have been the 1996 Special NRI Study and the 1997 Special NRI Study; these two special studies were conducted using special imagery in order to investigate effects of the Federal Agricultural Improvement and Reform Act of 1996 and high commodity prices on conservation practices and cropping patterns. This series of special studies will continue for several more years; the 6,000 PSUs contained in the study will be analyzed intensely to investigate progress being made regarding several conservation initiatives. Also, NRCS had conducted a 1995 NRI Erosion Update Study to look at changes occurring between 1992 and 1995, with main emphasis on progress made toward erosion reduction goals.

Data collection for the NRI is now handled by multidisciplinary teams that rely mostly on photointerpretation techniques (including the use of county office records and numerous other ancillary materials); most data collection teams now have multiple state responsibilities. All sample sites were field-visited for the 1982 NRI, but only one-fourth were field-visited in 1992; for the 1997 NRI, less than 20 percent will be field-visited. In lieu of field visits, data collection specialists use aerial photography and other remote sensing materials, county office records, soil survey maps, and many other ancillary materials. The data gatherers are responsible for a thorough edit and verification of all previously gathered data to ensure that year-to-year differences reflect actual changes in the resource conditions rather than differences in the perspectives of two different specialists or changes in technologies and protocols. Many editing procedures and other quality assurance procedures are utilized. The 1997 NRI is employing new data handling and telecommunications technologies featuring personal digital assistants and a host data base server (at Iowa State University) that will substantially enhance quality, efficiency, and timeliness for data collection [Nusser, Thompson and Delozier 1996].

Most data elements (variables) are collected at the sample points; there are some items collected for the entire PSU. There is also a third type of data, called “County Base Data”, that are collected on a 100 percent or census basis rather than just for sample sites; these data are used as control totals in the statistical weighting procedures, and are now obtained via GIS techniques [Nusser and Goebel 1997].

Information contained in the NRI includes:

- Soil characteristics and interpretations (such as slope, depth, land capability class/subclass, prime farmland, salinity or acidity, flooding frequency),
- Earth cover (such as trees, shrub, grass),
- Land cover and use (such as crop type, grazing, recreation),
- Erosion (such as sheet and rill, wind),
- Land treatment (such as conservation tillage, irrigation, windbreaks),
- Vegetative conditions (such as range condition and species, wetlands),
- Conservation treatment needs (such as erosion control, irrigation management, forage improvement),
- Potential for cropland conversion,
- Extent of urban land,
- Habitat diversity, and
- Cover maintained under the Conservation Reserve Program, where applicable.

In addition, the NRI is linked to NRCS's extensive Soil Interpretations data base, and data from other sources can be integrated with the NRI through geospatial linkages. This concept is discussed briefly in the next section in the context of simulation modeling based upon the NRI.

Quality assurance goals and procedures can be found in *1997 National Resources Inventory Quality Assurance Plan*, which is located on the Internet at *www.ftw.nrcs.usda.gov/nri/other_matl.html*. A Quality Evaluation Study will be conducted, so that data users can be provided information on the quality of NRI data. One facet will be to conduct an independent replication of data collection on a subsample of 5,500 PSUs (out of the original sample), to obtain statistical descriptions of the variability associated with the data collection process. A second facet will be the collection of additional data on 2,400 of the PSUs in order to evaluate protocols and test alternative measures that may be used in future inventory operations. Francisco [1986] describes operational procedures and findings for a quality evaluation study of the 1982 NRI.

3.4 Statistical Estimation Techniques

Statistical estimation for the NRI is discussed by Nusser and Goebel [1997], Goebel, Reiser and Hickman [1985], Goebel and Baker [1987], and Nusser, Breidt and Fuller [1998]. Statistical procedures are used to impute missing data for sample units not observed in 1987 and for those new to the sample in 1987 and/or 1992. Imputation is also used to generate "pseudo-points" that are needed to transfer the PSU and County Base Data to point level data [Breidt, McVey and Fuller 1996]. Small area estimation techniques are used to construct model-based estimates for urban and built-up acreages. Thousands of "controls" are incorporated into the construction of the weights. The final set of weights is constructed using a sequential ratio estimation procedure; each sample point receives one weight that is used for all analyses.

4. Utilization of NRI Information for Modeling and Policy Development

4.1 Overview

Proper assessment of the Nation's natural resources is not feasible without proper data. The NRI data base has been designed, developed and assembled with the specific goal of supporting policy development and program implementation. Natural resource and environmental issues are temporal and geospatial in nature, and the data base is a unique source of information that provides analysts a means to properly study these issues.

To credibly study these issues, the data base must be of high quality, statistically defensible (i.e. techniques carefully developed and accepted by the scientific community), and constructed in a manner that facilitates assessment and analysis. Sections 2 and 3 of this paper have presented an overview of NRI statistical design and operations. Many other considerations have gone into development of the NRI data base; the experiences of analysts and other data users over the past decades have strongly influenced the design and format of the current NRI data base.

The NRI data base contains millions of pieces of information. It can serve as the foundation for inspection and analysis of the condition of our Nation's natural resources. It indicates, for example, how our Nation's non-Federal lands are being used, what condition the resources are in, and how patterns have changed over time. The data base can serve as a powerful and unique tool — it can serve as the basis for valuable spatial and temporal analysis, whether used in conjunction with other data bases or by itself — and it is invaluable when studying land use and natural resource policy issues.

Many factors going into construction of the NRI data base deal with the issue of having an easy-to-use data base; these are in addition to quality and credibility issues previously mentioned. The NRI program would not be worthwhile if the data are not being used by a large and varied number of individuals, units and agencies. The data base must contain relevant quality data, must be readily accessible, and must be constructed in a manner that encourages its utilization.

An important feature of the NRI data base is that all data are put into one easy-to-use format, which is referred to as *point type* information; this facilitates manipulation of the data — for example, data are easily accessed through most statistical and data base management computer packages. The data are multi-resource or multivariate, covering many themes and facets; it is much easier to have properly correlated data for specific point samples than for broader sample units. The NRI data base is complete; it is fully populated and contains no missing values, which is not the case for many other data bases — statistical imputation procedures are used for the NRI [Nusser and Goebel 1997, Breidt et al. 1996]. Data base construction and data collection procedures are designed to ensure that each new NRI data base contains data that are consistent over time, so that legitimate temporal analyses can be performed; as mentioned previously, data collected during previous inventories are updated for each new inventory to reflect current technical criteria and protocols. The NRI data base contains linkages to NRCS's extensive soil interpretations data base and to other data bases; many linkages can be made geographically (spatially), while others can be made using various data themes, for example, land cover/use or forest cover type.

The NRI has been designed and developed as a means to investigate status and trends of natural resource conditions in the U.S. NRI data can be used in many ways and combined with other types of data to help inform policymakers and the public about these conditions, to support development of agri-environmental policies, and to guide conservation program implementation. The breadth of analysis possible utilizing NRI data is not discussed here. Rather, we present just a few basic findings from the 1992 NRI and give some indication of the value of NRI as a framework for simulation modeling.

4.2 Findings

NRI data have been used extensively for nearly two decades in national, regional and local planning, in university research, and for private sector analysis. The data have helped shape major environmental and land use decisions. NRI data form the basis for farm, conservation and natural resource legislation at the state and national levels. The U.S. Department of Agriculture (and other agencies) uses NRI data to assess current and future impacts of agricultural conservation programs and to help direct national conservation programs.

In recent years, NRI data have been used to educate and inform many segments of the American public. Many maps, graphics and tables of data have been made accessible through the Internet; numerous graphics with short narratives were prepared and released to thousands of newspapers and to various other media groups. A highlight of this information delivery process was the publication of *America's Private Land - A Geography of Hope* [USDA 1996]. This publication discusses a variety of resource issues in depth, assesses accomplishments of America's farmers and ranchers, and presents the challenge of maintaining the health of the Nation's privately owned land over the next 50 years. It is available on the Internet at *www.nrcs.usda.gov/CCS/CHopeHit.html.*

Land use and land use change are two of the basic elements needed in investigating many natural resource and conservation issues. There are approximately equal amounts (about 20 percent each) of cropland, non-Federal rangeland, non-Federal forest land, and Federal lands; the remaining area consists of pastureland, developed land, water areas, and various miscellaneous rural areas. Maps provide a partial perspective (in a spatial context) of how land is used in the U.S. [USDA 1996]. Numerous maps showing land cover/use are accessible on the Internet at *www.nhq.nrcs.usda.gov/land/index/cover_use.html*. Forest land predominates in the eastern half of the country, except for those areas in the center of the country where cropland is concentrated. Rangeland and Federal lands make up most of the western half of the country, which is characterized (in general) by lower rainfall, more mountainous terrain, and soils less suitable to cultivation. Land use changes for the period 1982 to 1992 are presented in *Summary Report: 1992 National Resources Inventory* [USDA 1994], and discussed by Kellogg, TeSelle and Goebel [1994]. Land use trends (for example, urbanization) are important to consider in geospatial analyses of agri-environmental issues.

Land use information coupled with detailed soils information is invaluable to analysis of agri-environmental policy issues. NRI sample data are linked to an extensive NRCS Soil Interpretation Records data base, which provides numerous characterizations and interpretations for the soil found at the sample site. "Prime farmland" is defined as *land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, and oilseed crops is also available for these uses*. Therefore, the classification "prime farmland" provides a simplified characterization of land quality taking into account the soil, land use, and climate factors (and suitability for agricultural activities); in general, these are the lands most intensively cultivated. About one-fourth of America's private rural land is characterized as prime farmland, and two-thirds of prime farmland is currently cropped; see *www.nhq.nrcs.usda.gov/land/index/prime.html*.

The NRI is useful because it provides properly correlated site-specific data on soils, land use and land use change, and other factors related to conservation issues for a large number of sample sites spread throughout the country. Soil erosion is one of the major issues addressed by the NRI; the NRI provides considerable data that enables many forms of complex analysis of problems associated with erosion, of progress made in recent years, and of impacts of proposed policies and programs [Kellogg et al. 1994]. Maps highlighting areas of cultivated cropland where soil erosion is excessive in relation to "tolerable rates" are quite useful to NRCS [USDA 1996]; see *www.nhq.nrcs.usda.gov/land/index/erosionmaps.html*. Many aspects of erosion can be analyzed, particularly in regard to how erosion is changing as a result of various programs and changes in management practices.

4.3 Framework for Simulation Modeling

The ability to use the NRI as a framework for simulation modeling has been more fully developed in recent years as geospatial analysis techniques have expanded and additional data have been successfully linked to the NRI. We briefly discuss two studies that treated NRI sample points as "representative fields" and simulated pesticide loss from farm fields in order to investigate potential environmental risks. One of the studies was a national level simulation focusing on 5 chemicals; the other investigated environmental risks associated with 64 chemicals for 36 watersheds in three large river basins.

The national analysis determined which watersheds had the greatest potential for the concentration of pesticide loss from farm fields to exceed ground water quality thresholds; potential for runoff loss was also investigated [Kellogg, Bagdon, Wallace, Plotkin and Hesketh 1997]. The GLEAMS fate and transport model was run for 170,000 NRI sample sites. Soils information, cropping history, and other attributes for an NRI sample point were used to develop field characteristics needed for the model. In addition, because the NRI survey does not directly collect information on chemical applications, pesticide loss concentrations were imputed onto NRI sample points based upon soil type, geographic location, and pesticide. Using the GLEAMS model, annual concentrations at the bottom of the root zone and at the edge of the field were estimated for a 20-year period and compared to water quality standards. Likelihood to exceed thresholds and the statistical weighting factor associated with each NRI sample point were used to estimate watershed level risk. The simulation was conducted for 5 pesticides (alachlor, atrazine, cyanazine, metolachlor, and simazine) and 13 crops (barley, corn, oats, peanuts, potatoes, rice, sorghum, sugar beets, sunflowers, tobacco, and wheat). Maps were generated to show potential for concentration of pesticide loss from farm fields to exceed ground water quality standards, by watershed. This indicates to NRCS managers where there is the greatest likelihood that technical assistance will be needed, if there is adoption of the U.S. Environmental Protection Agency proposal to require State Management Plans as a mechanism for restricting the use of a pesticide.

A second example of NRI-based simulation modeling is presented by Kellogg, Plotkin, Bagdon, Hesketh, Hugo and Wallace [1997]. Baseline environmental risk was estimated by running the GLEAMS model for 1,940 NRI sample points within the three river basins; models were then rerun to simulate the effects of alternative pesticide management practices. For the 1,940 NRI sample points, actual site-specific data on current pesticide use and other management practices were obtained for the field in which the NRI point is located. Simulations were conducted for 50 years of climate data. The Threshold Exceedance Units measure is an aggregate measure of risk for the watershed obtained by using the NRI statistical weighting factors to calculate weighted averages of the individual risk measure. "Before and after" maps show the importance of the NRI as a tool to help evaluate the impact of proposed agricultural and environmental programs and changes in management policies.

5. Meeting Future Needs for Information

The NRI plays a key role in development of conservation policy and programs for the Nation. It also serves to educate the public regarding natural resource issues and provides a comprehensive nationally consistent source of data to researchers in many fields. The NRI program will continue to evolve, as USDA and NRCS attempt to cost-effectively collect more timely and relevant information in order to address emerging agri-environmental issues. The NRI is already a multi-resource inventory, but it is being called upon to help analyze a broader spectrum of natural resource issues. This will be accomplished by developing a "continuous inventory approach," by incorporating various resource assessment tools, and by developing a multi-agency integrated inventory approach.

NRCS is developing a continuous inventory approach that features five inventory components and four supporting processes. This approach will more fully utilize the capabilities of its highly trained data gatherers and the sophisticated equipment and technologies that have been developed, as well as to better address emerging issues. The inventory components/products will be:

- An annualized foundation inventory (of the 300,000 PSUs) based upon remote sensing,
- On-site data collection (annualized) at a subsample of the 300,000 PSUs to support application of ecosystem based resource assessment tools with a focus on monitoring,
- Multi-spectral digital imagery (wall-to-wall products) that augment and complement the probability-based sample results,
- Special studies (ad hoc) that focus on current issues of interest (conducted one time or for a limited time period), usually utilizing a subsample of the 300,000 PSUs, and
- Locally-led studies (ad hoc).

The supporting processes will be:

- Quality assurance and maintenance,
- Partnerships,
- Utilization and dissemination of results, and
- Methods and technology development.

Resource assessment tools will be incorporated into the NRI methodology as they become capable of signaling, in a cost effective manner, where changes in management (or policy) are needed. These tools would also, then, be effective at evaluating the effects of changes in management or policy. Soil quality indicators will be a basic vital part of this methodology. The National Research Council of the National Academy of Sciences stated that protecting soil quality should be a goal of national policy to complement those already established for air and water quality; they stressed that the first step to improving the environment is the maintenance and/or enhancement of soil quality. The NRI is being investigated as a possible framework for providing more meaningful assessments of the quality and health of the soil resource base [Goebel et al. 1997], as well as various other landscape or ecosystem characteristics. Much work remains to define soil quality [Karlen et al. 1997, Seybold et al. 1997] and to develop assessment protocols that are affordable, can be related to needed changes in management, and are repeatable so that sample sites can be reliably monitored over time. There are also efforts to develop useable resource assessment tools (or protocols) for ecosystem characteristics such as grazing lands, wetlands, forest lands, and wildlife habitat.

Numerous efforts are underway to coordinate and integrate the many activities that currently attempt to monitor the environment. A National Science and Technology Council committee has proposed a framework that includes remote sensing, probability-based surveys, research into ecological modeling, long-term monitoring at purposively selected sites, and research station activities. Integration of probability-based terrestrial surveys is being pursued as a result of an inter-agency demonstration project conducted in Oregon; this study showed the feasibility of combining sampling frames and ecological measures from different disciplines and agencies [Goebel et al. 1996]. Plans are now being developed to implement the recommendations derived from that project; the first facet is to integrate the NRI and the Forest Inventory and Analysis program that has been conducted for decades by the U.S. Forest Service, which is also a USDA agency.

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