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MAJOR LAND RESOURCE AREAS AND ECOLOGICAL SITE DESCRIPTIONS: POTENTIAL DATABASES FOR MULTIPLE OBJECTIVE DECISION SUPPORT SYSTEMS

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ABSTRACT

Two agencies within the United States Department of Agriculture (USDA), the Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS) are working together in Arizona to improve management of rangelands through new research and improved technology. The ARS has been developing multiple objective decision support systems that will help NRCS evaluate complex natural resource concerns and rangeland management alternatives. The NRCS examines soil, water, air, plant, animal, and human (SWAPA+H) values when providing conservation planning assistance to grazing land managers. New concepts in range management, such as rangeland health and state and transition theories are the focus of research to begin incorporating rangeland health into SWAPA+H. Two historical databases that provide valuable information during this time of new technology development are the USDA-National Soil Information System and the National Ecological Site Information System. Since the 1960's, NRCS has been using the soil and potential natural vegetation databases as the basic units of a hierarchical natural resource classification system called Major Land Resource Areas (MLRA's). This system provides a basis for making decisions about national and regional agricultural concerns, helps identify needs for research and resource inventories, provides a broad base for extrapolating the results of research within national boundaries, and serves as a framework for organizing and operating resource conservation programs.

KEYWORDS conservation; ecology; rangeland; soils; technology

1 Introduction

There is a need for improved scientific understanding of natural resource processes as well as a need for the development of knowledge bases, databases and new technology to address the increasing demands being placed on our limited rangeland resources.

In 1990, the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) developed a tool, known as Conservation Practices Physical Effects (CPPE), to facilitate comprehensive natural resource planning. An extensive list of resources, including aspects of those resources that could potentially be degraded, was developed. These resources include: Soil, Water, Air, Plant, Animal and Human Considerations (SWAPA+H). An equally comprehensive list of conservation practices to ameliorate problems with resources has also been defined, as has a CPPE matrix that indicates qualitatively the range of potential effects of the conservation practices on natural resource problems.

Two databases that provide valuable basic information with regard to new technology development and implementation are the USDA-National Soil Information System (NASIS) and the National Ecological Site Information System (ESIS). USDA-NRCS has been using the rangeland ecological site (formerly known as range site) as the basic unit for rangelands of a hierarchical natural resource classification system called Major Land Resource Areas (MLRA's) since the 1960's.

2 National Soils Information System

Soils are formed from interactions of five factors: climate, parent material, topography, vegetation, and time. The soil provides support and serves as the storage medium from which plants extract water and nutrients. Variation in the quantity of water in the soil profile is the major cause of variations in vegetative production. Soil characteristics have a major impact on water use and management in agriculture. Surveys of soil characteristics are developed by the NRCS using observations along soil delineation boundaries and traverses as well as by determining map unit composition by field transects.

The NRCS has established three geographic databases representing different intensities of mapping (Soil Survey Staff-NRCS, 1997). The State Soil Geographic database (STATSGO) has been developed at a scale of 1:250 000 and archived in one by two degree topographic quadrangle units. Map unit composition is determined by transecting or sampling areas on the more detailed maps and expanding the data statistically to characterize the whole map unit. Map units are grouped as soil associations, which are representations of soil patterns in the landscape. Soil associations consist of two or more dissimilar components occurring in a regularly repeating pattern in the landscape (USDA-SCS, 1993). The major components of a soil association can be separated at a scale of 1:24 000 but are sufficiently different in morphology or behavior that the map unit cannot be called a consociation, a narrowly defined phase of a soil. The proportion of these two components may vary appreciably from one delineation to another, and the total percentage of inclusions in a map unit that are dissimilar to any of the major components does not exceed 15% if limiting and 25% if non-limiting. The STATSGO database was designed primarily for regional, multi-state, river basin, state, and multi-county resource planning, management, and monitoring.

Soil Survey Geographic (SSURGO) maps are made at scales ranging from 1:12 000 to 1:63 360 and digitized so that they duplicate the original county soil survey maps. These digital databases contain more detailed information on soils and soil attributes than the STATSGO database and can be used by landowners, townships, and counties to make land use and land management decisions. These data are archived in 7.5-minute USGS topographic quadrangle units and are patched together to create county versions of SSURGO.

The National Soil Geographic (NATSGO) database is the most general geographic database. It contains digital data developed nation-wide on a scale of 1:7 500 000. The database consists of spatial data, such as the digital MLRA map and attribute data, including data on map unit components and composition that are derived from the STATSGO file.

3 Major Land Resource Areas

A land classification system developed by USDA and described in Agricultural Handbook No. 296 (USDA, 1981) divides the United States into several hierarchical categories based on natural resource characteristics and land uses. The information provided in this handbook affords resource managers a basis for making decisions about national and regional agricultural concerns, identifies needs for research and resource inventories, provides a broad base for extrapolating the results of research within national boundaries, and serves as a framework for organizing and operating resource conservation programs.

Land resource categories used at national levels are Land Resource Units (LRU), Major Land Resource Areas (MLRA), and Land Resource Regions (LRR). LRU's are geographic units, usually several thousand hectares in extent that are characterized by a particular pattern of soils, water, climate, and land uses. They are the basic units from which MLRA's are determined. LRR's are the largest scale designation of an area of land that is comprised of a number of MLRA's. There are 20 LRR's and 177 MLRA's, including their subdivisions within the continental 48 states.

A Major Land Resource Area (MLRA) is an area of land that is associated through geography, geology, soils, climate, physiographic features, potential natural vegetation, water resources and land uses. The dominant soils of an MLRA are identified according to the principal soil suborders, great groups, and representative soil series. Traditional applications include soil surveys, forest and rangeland ecological site description interpretations, and predictive responses of natural resources to treatment and management. Characteristics of MLRA 41 (Southeastern Arizona Basin and Range), which covers parts of Arizona and New Mexico, are given in the following example:

Land Use:	Most of area is used for grazing
Elevation and topography:	800 to 1400 m most places
	1500 to 1800 m mountains

Climate:	Average annual precipitation of 275-375 mm, 900 mm at higher altitudes
Water:	None of the streams flow continuously
Soils:	Orthents, Fluvents, Ustolls, Ustalfs, and Argids Thermic and mesic soil temperature regimes, mostly aridic moisture regime
Potential natural vegetation:	Area supports forest, savanna, semi-arid desert grassland, and desert shrub vegetation

Each LRR is comprised of a number of MLRA's which, in turn, are comprised of a number of LRU's which are made up of multiple rangeland ecological sites. The following example shows one of three Resource Units within LRR D, MLRA 41, and several rangeland ecological sites within the Resource Unit as used in Arizona.

- **LRR** *D - Western Range and Irrigated Region*
  - **MLRA 41** *Southeastern Arizona Basin and Range*
    - **Land Resource Unit 41-3** *Southern Arizona Semi-Desert Grassland*
      - **Ecological (Range) Sites**
        - Flooded (bottom position)
          - *Sandy bottom 30-40 cm annual precipitation*
          - *Loamy bottom 30-40 cm annual precipitation*
          - *Clayey bottom 30-40 cm annual precipitation*
        - Not flooded (upland position)
          - *Sandy upland 30-40 cm annual precipitation*
          - *Loamy Upland 30-40 cm annual precipitation*
          - *Sandy Loam Upland 30-40 cm annual precipitation*
          - *etc.*

Synecological studies on rangelands, begun in 1939, quantified departures of current types of range vegetation from potential climaxes for specific sites (Dyksterhuis, 1946; 1948). Utilizing these results and those from many other studies, along with the widespread experience of the Soil Conservation Service (now NRCS), the synthesis of a new system of range evaluation based on quantitative ecology was reported ten years later (Dyksterhuis, 1949). The new system involved the identification and delineation of range sites (rangeland ecological sites) as a taxonomic unit.

The ecological site is the basic unit of a hierarchical natural resource classification system, and it is important that resource managers recognize these units, regardless of the scale at which a resource inventory is made. It is at the ecological site level that sampling can be accomplished without encountering undue variation and for which management outcomes can be predicted. Basic ecological sites must be identified and described so that natural resource managers can utilize this information for inventories and management. An ecological site is a distinctive kind of land that differs from others in its ability to produce a characteristic natural plant community. It is the product of all environmental factors responsible for its development and is capable of supporting a native plant community, typified by an association of species that differs from that of other ecological sites in the kind or proportion of species or in total production (USDA-NRCS, 1997).

Ecological sites are taxonomic units, not mapping units. However, when an ecological site occurs over a relatively large area, the site can be designated as a mapping unit, even on relatively small-scale imagery. When rangeland ecological sites are highly patterned because of site factors such as slope, aspect, soils, etc., the sites may not equate to mappable units except on very large-scale imagery. Thus, the mapping unit may be comprised of a combination of sites, but the arrangement and proportion of the individual sites within the mapping unit determine the value of the unit for specific uses such as livestock grazing, wildlife habitat, recreation, or urban development. Inventory techniques should provide for recognition and sampling at the rangeland ecological site level.

4 State and Transition Models

The ecological theories of succession and retrogression (USDA-NRCS, 1996) were developed into a method of rangeland condition assessment in the 1940's. This method requires rangelands to be classified into range (ecological) sites. Where the succession-retrogression model (Dyksterhuis, 1949) works well, as in the true tall grass prairie regions for which it was developed, it is a powerful tool. Unfortunately, it has not worked as well to describe ecological condition in semi-arid and arid regions where half-shrubs and shrubs are an important component of most plant communities (Shiflet, 1973). This has led to the consideration of alternative concepts to classify, inventory and monitor rangelands. The state and transition model is one such concept and is very valuable for explaining ecosystem change.

The state and transition model helps explain how rangeland ecosystems change when a system can evolve in different ways rather than follow a single pathway (Clements, 1916); when change occurs very quickly; when changes are permanent; and when detailed explanation of the transitions that cause change is required (USDA-NRCS, 1996). Thresholds are levels of disturbance or change that, once exceeded, alter the stability of an ecosystem and drive it towards a different state. States that are resistant to change are called steady states. These steady state plant communities transition as a result of events such as long periods of above-average moisture or drought, fire, insect or disease outbreak, or human actions. For example, thresholds can be reached if soil erosion and nutrient loss are severe. This may result in a change in the water cycle due to a lower rate of water infiltration, more rapid runoff, and restricted plant growth during the growing season. The original plants may no longer be able to survive or compete with invading plants.

5 Rangeland Health

The concept of rangeland health is being used to help predict the current risk of moving from one steady state to another with respect to sustainability. Rangeland health has been defined as the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained (National Research Council, 1994, p.4). Rangeland degradation reduces the diversity and amount of the values and commodities it can provide, and severe degradation can be irreversible. Most observers agree that rangeland degradation was widespread on over-grazed and drought-plagued rangeland across the southwestern United States at the turn of the century. The present state of health of U.S. rangelands is a matter of intense debate. A major part of this debate results from confusion caused by the use of agency-specific terminology by each of the federal agencies charged with identifying range conditions, as well as agency-specific inventory and assessment methods.

The importance of gathering the information needed to protect and sustain the capacity of rangeland ecosystems to provide the values and commodities desired by society has been repeatedly recognized in national legislation in the U.S. The NRCS, USFS, and BLM are three government agencies that have all been mandated to provide the assessments of rangeland ecosystems needed to protect the quality and sustained yield of renewable resources.

Range condition (NRCS), ecological status (U.S. Forest Service (USFS)), and Bureau of Land Management (BLM) assessments have historically been the primary methods used to evaluate rangelands. Now, scientific debate over the use of various different methods to assess rangeland ecosystems has intensified, leading to disagreements over the proper interpretation of past and ongoing range condition assessments. It is common for different individuals to evaluate the same data and reach very different conclusions about the state of U.S. rangelands and the value of the data. A confounding problem is that the data that are available for rangeland assessment have been obtained from many different sources and were collected using many different methods.

The rangeland health model, developed by the National Research Council (NRC) Committee on Rangeland Classification, was established to evaluate the methods used by federal agencies to classify, inventory, and monitor rangelands. The Committee recommended that the minimum standard for rangeland management should be to prevent human-induced loss of rangeland health, and to evaluate rangelands from the basis of a common land unit classification, the rangeland ecological site (National Research Council, 1994).

The NRC further recommended that rangelands be considered healthy "if an evaluation of the soil and ecological processes indicates that the capacity to satisfy values and produce commodities is being sustained"; at risk "if the assessment indicates an increased, but reversible, vulnerability to degradation"; unhealthy "if the assessment indicates that degradation has resulted in an irreversible loss of capacity to provide values and commodities." Where rangeland health is preserved a variety of management options and land-uses may be appropriate (National Research Council, 1994).

6 SWAPA + H

In the United States, the USDA-NRCS and other institutions have developed technology to support land users for many decades. Major components of the NRCS conservation planning technology include a planning method, a hierarchical land classification system (Land Resource Regions and Major Land Resource Areas of the United States), natural resource databases (soils and ecological sites), resource problem definitions, and management practice standards. The BLM and the USFS also have a long history of experience in managing rangeland resources, but with less emphasis on technology transfer than NRCS. Research needs of the federal land management agencies are met either in-house or by universities, Cooperative Extension or through the Agricultural Research Service (ARS).

To share information about range management issues, it is necessary to have common definitions for both management practices and the resource problems they address. National resource problem definitions and management practice standards have been developed by the NRCS (USDA-NRCS, 1998). Resource problems are defined in relation to the Soil, Water, Air, Plant, Animal, and Human (SWAPA+H) categories, which are used in conservation planning processes. New concepts such as rangeland health can be incorporated into existing tools such as SWAPA+H using new technologies such as multiple objective decision support systems.

7 Multiple Objective Decision Support Systems

A prototype Decision Support System (DSS) (Yakowitz and Lane, 1992) has been developed to evaluate the environmental and economic consequences of alternative ranching practices. The DSS, with an embedded computer simulation model, ranks the feasible management practices using multi-objective decision theory. The method combines the use of graphically based scoring functions and some simple yet powerful linear programs to rank the alternative practices. This ranking is achieved in an objective manner under the guidelines of the decision-maker. The primary intended user group of the system is the Natural Resources Conservation Service (NRCS) although other groups will also use it.

A rangeland health assessment is the result of summing the results from three functional categories: watershed function and soil stability, distribution of nutrient cycling, and energy flow and recovery mechanisms. There are seventeen individual attributes allocated to one or more of these categories that are weighted independently of each other. A simple algorithm based on linear and dynamic programming principles implemented in a computer spreadsheet allows one to quickly compute the possible range of overall site ratings from the most optimistic to the most pessimistic. The decision support system is particularly useful for examining land areas from numerous, often conflicting, decision-making viewpoints or by multiple decision-makers.

An important benefit of the prototype MODSS for rangeland health evaluation is that it provides an objective means of combining indicator values, providing an index range that reflects measured data for a site. The MODSS reveals the sensitivity of each site assessment to a decision maker's priorities and allows examination of intermediate indices while also providing the opportunity to examine the effect of changing the importance order of indicators (Yakowitz et al., 1997).

8 Summary and Conclusions

By combining the efforts of two federal agencies, ARS and NRCS, improved scientific understanding, expanded databases, and new technology are being developed to improve the management of rangelands. NRCS's historical soils and ecological site databases, the MLRA land classification system, and SWAPA+H provide a pre-existing framework for technology development. Given this framework, there is a great potential to document the state-of-the-art knowledge about management effects on different resources on a given ecological site. This greatly improves a land managers' ability to interpret and apply the results of scientific research concerning the management of rangeland resources that would not otherwise be available to them. The rangeland health concept incorporates ecosystem sustainability into new tools, such as a prototype MODSS, which are used for rangeland resource assessment and evaluation of land management alternatives.

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