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Viewpoint: Delineating ecological sites

JEFFREY A. CREQUE, SCOTT D. BASSETT, AND NEIL E. WEST

Authors are former graduate research assistant, GIS specialist, and professor, respectively. Creque and West are associated with the Department of Rangeland Resources, Utah State University, Logan Utah 84322. Creque's current address is: P.O. Box 1004, Bolinas, Calif. 94924. Bassett, formerly associated with the Department of Fish and Wildlife Resources at USU, is currently at the Harvard University School of Design, Cambridge, Mass. 02132.

Abstract

Both the Society for Range Management's (1995) Task Group on Unity in Concepts and Terminology (UCT) and the Natural Resources Conservation Service (1997) have recommended use of the ecological site as the fundamental land unit for evaluation of rangeland condition and trend. While the ecological site concept may be relatively straightforward, in practice the spatial definition of ecological sites within a management unit can prove problematic. This paper presents the use of readily available digital information in a GIS framework to delineate ecological sites within a pinyon-juniper/sagebrush semi-desert dominated landscape in Central Utah. An existing model of pre-Euroamerican pinyon-juniper woodland dynamics was combined with the site classification to evaluate landscape dynamics. We also created a map of landscape pattern of potential utility to land managers. The mapping capabilities of GIS offer a simple and remarkably adaptable technique for visual modeling of landscape pattern to assist in meeting a wide array of land management objectives. However, the "objective" delineation of ecological sites must be recognized as being necessarily based on a priori user-selected criteria.

Key Words: pinyon-juniper woodland, sagebrush semi-desert, landscape vegetation pattern, ecological site, range site, GIS, landscape ecology

Resumen

Tanto la comisión de la sociedad de Manejo de Pastizales (1995) para la unificación de conceptos y terminologia (UCT), como el Servicio de Conservación de Recursos Naturales, han recomendado el uso del término sitio ecológico, como la unidad fundamental para la evaluación de condición y tendencia en areas de pastizal. Aunque el concepto ecológico de sitio parecería facil de implementar, en la práctica la definición espacial de sitios ecológicos dentro de unidades de manejo, puede resultar problemática. Este artículo muestra el uso de información digital disponible en formato GIS (sistemas de información geográfica), para delinear sitios ecológicos dentro de un paisaje dominado por pino-junipero/artemisia en región Central de Utah. Basado en un modelo pre_Euroamericano existente sobre dina-mica de bosques de pino_junipero, la clasificacio-n de sitio permitio-la evaluacion de la dina-mica de paisajes cambiando a travez del tiempo y la creacio-n de un mapa de patrones del paisaje con utilidad potencial para manejadores del paisaje. Las características para elaboración de mapas con GIS ofrece una simple y adaptable técnica para modelaje visual de los patrones del paisaje que apoyan una amplia variedad de objetivos de manejo. Sin embargo, la delineación 'objetiva' de sitios ecológicos debe reconocerse que estáa basada en criterios a priori seleccionados por el usuario.

The Society for Range Management's (1995, p. 277) Task Group on Unity in Concepts and Terminology (UCT) and the Natural Resources Conservation Service (1997, p. 3.1-1) have argued that the ecological site concept must be the cornerstone of any inventory of the rangelands of the United States. Further, they have recommended the ecological site as the fundamental land unit for evaluation of rangeland condition (SRM 1995). The purpose of this paper is to: 1) argue that such a definition is in one sense arbitrary and in another sense strictly a function of the purposes for which such sites are defined; and 2) give a simple example of how GIS technology (Chrisman 1997) can aid in defining such sites for research and management needs.

Ecological site definitions have varied over time and across disciplines (Leonard et al. 1992, Allen and Diaz 1989, Hironaka 1986, Hall 1985, Mason 1985, Ross 1985, Daubenmire 1984, Hoffman 1984). The Society for Range Management (SRM 1989) defines an ecological site as, "an area of land with the potential to produce and sustain distinctive kinds and amounts of vegetation under its particular combination of environmental factors, particularly climate, soils and associated native biota." However defined, the call for recognition of the ecological site as the basic land management unit renders the capacity to classify and map such areas an essential component of any management effort.

In range science and soil science, the designation of ecological sites has developed from recognition of the need for partitioning of landscapes into tractable management units; areas

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of land classified under the same ecological site designation can be expected to exhibit similar characteristics with respect to site potential and response to management. By definition, significant differences in fundamental characteristics do not exist between spatially disjunct examples of the same collective ecological site (Mason 1985, Ross 1985, Daubenmire 1984). At the same time, site similarity does not guarantee uniform plant cover even within the same ecological site because of differences in use or disturbance history on different portions of that site that are called "stands" (Aber and Melillo 1991, p. 11).

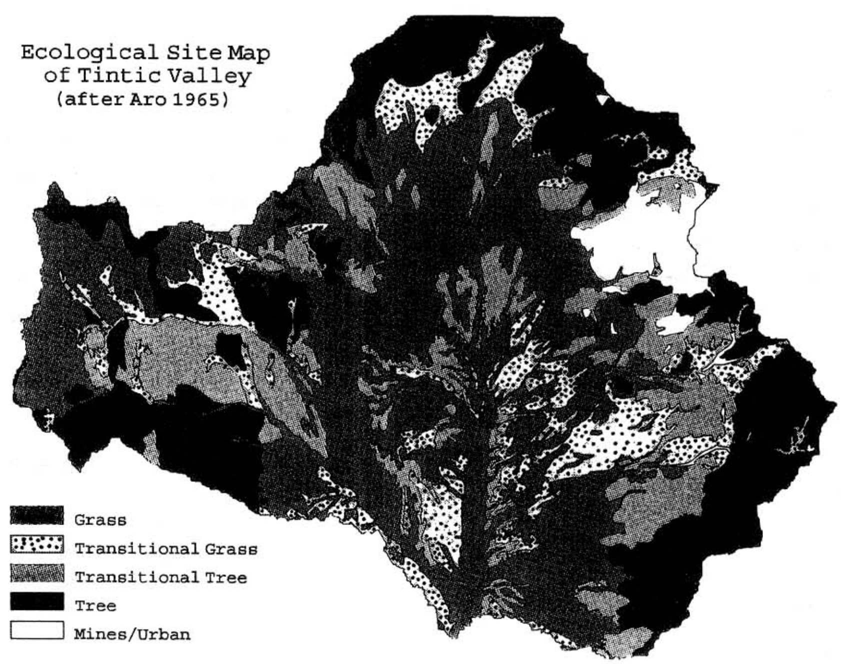
While the criteria for ecological site classification appear quite straightforward conceptually, in practice division of a landscape into distinct ecological sites can prove difficult indeed. Consider, for example, a topographically diverse landscape containing 25 mapped soil phases, slopes ranging from 0 to 100%, aspects represented by every direction of the compass and a range in elevation spanning several hundred meters. If every combination of soil and microclimate as reflected in slope, aspect and elevation differences is considered, several hundred thousand "unique" ecological sites may be recognized as occurring within this landscape. While it is possible to imagine research scenarios for which such a detailed classification might prove useful, most landscape management objectives can, and must, be met using a greatly simplified ecological site classification scheme. For this hypothetical landscape, for example, grouping slopes, elevations and aspects each into 4 classes while retaining all 25 soil phases results in the identification of "only" 1,600 ecological sites. For purposes of most practical management objectives, this is still an intractable number, suggesting the need for some grouping by soils and other factors, such as elevation. If we group our soils into 4 logical units and reduce our elevation classes to 2, while retaining 4 slope and aspect classes, we now have 128 ecological sites. This is starting to look reasonable, but further reduction, perhaps by grouping percent slope into 2 classes and aspect into 2 (eg., "northerly" and "southerly"), would bring our classification down to 32 sites, a number, for the sake of this example, we will be content to live with.

Application: An Example

This approach to purpose-specific, objectively derived ecological site delineation was used to explore the role of fire in the determination of pre- and post-Euroamerican landscape vegetation pattern in a 29,000 ha pinyon-juniper/sagebrush semi-desert dominated watershed in central Utah (Creque 1996). Using an existing model of 'fire prone' and 'fire proof' sites (Sauerwein 1981, Aro 1965), an ecological site map of the study area was derived using a straightforward, GIS-based methodology of potential utility for management of this and other landscapes (Fig. 1).

Aro (1965) argued, "The most consistent indicator of an original (pre-livestock) pinyon-juniper site is the stoniness or coarseness of the soil...Rapid infiltration, deep penetration and low soil moisture tension at these sites favor dominance of woodland over grassland." He identified narrow ecotones between woodlands and grasslands at topographic breaks from stony upper slopes to non-stony, gently-sloping lower sites. Mean woodland slope was found to be 25%. Grasslands showed a mean slope of 15%, which was considered high due to failure to extend sampling transects further into the grassland zone (Aro 1965). Sauerwein (1981), drawing on Aro's work, offered stoniness and slope as the 2 primary considerations in juniper to grass conversion projects. He argued surface coverage by stone or bedrock is the "simplest and best" site indicator, with <15% stone cover offered as a requirement of sites to be considered for conversion to grass.

While this approach to site classification is ultimately based on effective precipitation (Stevens et al. 1974), both Aro (1965) and Sauerwein (1981) explicitly state that a change in fire regime was responsible for observed expansion of pinyon-juniper woodland into grassland areas. Both argued that slope and soil texture together offer reasonable criteria for identifying "true" woodland, or "fireproof," sites, i.e., sites that would be woodland even in the absence of fire suppression, livestock or other post-Euroamerican settlement factors (Sauerwein 1981). It follows that if Aro and Sauerwein's model is correct, their ecological site criteria could be used to derive pre-Euroamerican settlement vegetation pattern within a fire-structured pinyon-juniper/sagebrush semi-desert dominated landscape. The following procedures were employed to map the landscape pattern resulting from the application of this model of pre-Euroamerican landscape dynamics.



Materials and Methods

The study area was defined as a watershed using Digital Elevation Models (U.S. Geological Survey 1987) for the six, 7.5 minute US Geological Survey quadrangles (30m resolution, USGS 1994) covering the study area. Areas contributing water run off to a predetermined pour point (Jenson and Dominque 1988) were considered to fall within the study area. Locations outside the extent of the watershed were not considered in the study.

Soils information digitized from planimetric maps provided the second form of digital information for the study (Soil Conservation Service 1994). Some missing digital soil polygon data were digitized from a paper copy of the soil survey for that part of the study area (Trickler and Hall 1984). Over 50 soil phases were contained within the study area. Because Aro and Saurwein's model considers only 2 factors, soil texture and percent slope, in ecological site determination, only these 2 factors were considered in defining the ecological sites derived in this study (Creque 1996). This information was derived from soil polygon attribute data contained in the study area soil survey (SCS 1994, Trickler and Hall 1984). Use of 2 classes of each factor resulted in delineation of 4 ecological sites; a 'tree' or 'fireproof' site, a 'grass' or 'fireprone' site and 2 transitional sites. A slope class > 15%, with surface stoniness > 15% placed a site in the 'tree' category. A slope class < 15%, with a surface stoniness < 15%, placed a site in the 'grass' category. Where texture was below threshold and slope above threshold, the site was classified as 'transitional grass,' while if texture was above threshold and slope below threshold, the site was classified as 'transitional tree.'

Results and Discussion

Applying the above criteria, 4 ecological sites, plus a 'disturbed/urban' site category, were mapped within the study area (Fig. 1). Such ecologically-based land unit classifications are necessary for effective communication among resource managers (Allen and Diaz 1989). Lack of a uniform ecological site definition across natural resource disciplines has been historically problematic (SRM 1995, Leonard et al. 1992, Allen and Diaz 1989, Hironaka 1986, Hall 1985, Mason 1985, Ross 1985, Daubenmire 1984, Hoffman 1984). We suggest that this conflict derives from the mistaken assumption that ecological sites are objectively real phenomena separate from the management or theoretical purposes their definition serves.

In practice, the process of ecological site definition necessarily demands consideration of the organism(s) of interest, spatial scale, management objectives, etc. As in the example given here, slope, aspect, soils, elevation, etc. ***appear*** to be objective site criteria; however, attempting to map all possible combinations of these elements on a typical rangeland landscape results in recognition of hundreds of thousands of potentially distinct sites. Such a classification may serve some purposes, e.g., stratification of research plots. However, most managers will want to make some broad generalizations about slope classes, soil groups, elevational bands, etc., to render their classification usable.

Clearly, the purposes for which a classification is derived will determine how that classification is developed. Hironaka (1986) correctly viewed the diverse classification schemes represented by such concepts as habitat type, range site and community type as complementary, rather than contradictory, and suggested that by incorporating such concepts into a hierarchical information storage and retrieval system, maximum utility of such a database for land management purposes can result. Geographic information systems (GIS) provide a useful framework for entering such information into a database of maximum flexibility for a variety of management objectives. By permitting the overlaying of selected layers of geographically referenced information, the GIS facilitates the mapping of ecological sites, habitat types, community types, stands, or any such units of land classification, however defined by the user. Once site criteria appropriate to the question at hand are delineated, GIS technologies allow managers to map those sites as elements within a larger spatial context. The GIS environment offers a way to derive those generalized classes, to visually render the results, and test assumptions about the classification.

Conclusion

Variation tends to be the rule rather than the exception in the world of natural resource management. While a degree of variability within a managed system is tractable, attempting to account for variation at all scales in space and time is usually well beyond the capacity or needs of the manager (Leonard et al. 1992). Consequently, an effort is made to classify similar areas within a management unit into categories which can reasonably be expected to respond to similar treatment in similar fashion. The purpose of any site classification must determine the criteria used to develop that classification. In the case study reported here, the abiotic factors of slope and soil surface texture were considered both necessary and sufficient for ecological site definition. Other management applications will require a similar process of selection of appropriate variables to be incorporated into site definition. The site classification approach presented here is flexible enough to encompass as many layers of information as considered relevant for the site classification needs of the task at hand. Our procedures are offered as an example of how managers can use GIS to derive some degree of order from the potential chaos of ecological site classification, ***once the objectives of such a classification have been clearly defined.***

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