Results of the Dane County Land Records Project

Bernard J. Niemann, Jr., Jerome G. Sullivan, Stephen J. Ventura, Nicholas R. Chrisman
Department of Landscape Architecture and the Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI 53706
Alan P. Vonderohe, David F. Mezera
Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI 53706
D. David Moyer
National Geodetic Survey and the Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI 53706

ABSTRACT: This paper presents the results of the Dane County Land Records Project, a four-year research venture involving numerous local, state, and federal agency cooperators. The project has developed, tested, and evaluated a concept for a multipurpose land information system. Components of this concept have included reliance on individual data layers maintained by legislatively mandated agencies and a common mathematical reference system to permit integration of the layers. The project investigated means to improve data input efficiency through scanners, satellite geopositioning, and remote sensing imagery. The project also investigated means to improve interdisciplinary and interagency efforts, using cooperative agreements, weekly project meetings, and user training. The project has demonstrated the potential of multipurpose land information systems to significantly improve both the efficiency and equitability with which rural land management programs are implemented.

INTRODUCTION

FOR MANY YEARS, the capabilities of mapping technology have set the limits of the information available for land management. While the law might require decisions to be carried out with certain information, planners and other land managers have had to make do with the "best available information." Historically, one of the missing elements has been ownership information, or an identification of those impacted by planning proposals. In the pre-digital period, the ownership record was typically ignored due to technical limitations that will not apply under the new technology.

The case of soil erosion planning provides an example of the evolution of an environmental management program. Soil conservation became a national issue during the 1930's dustbowl era. Despite substantial efforts since then, soil erosion is still a major problem. For 50 years, soil conservation programs have provided technical and monetary assistance for willing farmers, in isolation from other programs. Recently, this activity has been transformed into a quasi-regulatory program integrated with many others. However, information technology has not yet played a direct role in this process.

The State of Wisconsin has created a program to reduce soil loss. Some soil conservation district staff see this as a simple continuation of past policies and procedures, but there are some fundamental shifts in information requirements. The program is described in Chapter 92 of Wisconsin Statutes (1981) and implemented in Administrative Rule Ag 160 (1984). The statute gives an overall description of the soil erosion control plan:

> Each land conservation committee shall prepare a soil erosion control plan which does all of the following: ...
> 2. Identifies the parcels and locations of the parcels where soil erosion standards are not being met. ...[92.10 (5)a]

The administrative rule specifies the program goals in greater detail:

> The goal of the soil erosion control program is to reduce soil erosion caused by wind or water on all cropland in Wisconsin to T-value by the year 2000. T-value means the maximum average annual rate of soil erosion for each soil type (specified in the *SCS Technical Guide*) [Ag160.03 (16)]
> For watersheds or other cropland areas determined by the land conservation committee to be of highest priority, the soil erosion control plan shall include detailed estimates of cropland erosion rates. Estimates shall be sufficiently detailed to permit the identification of *individual parcels* of cropland which are in need of erosion control practices. [Ag160.05 (4b)] (emphasis added)

After the soil erosion planning process was put in place, the Wisconsin Legislature increased the need for integrated land information. A major state budget item is Farmland Preservation, which provides a state income tax credit for payments of local property tax on agricultural parcels. In return for the tax credit, the farmer must keep the land in agricultural use, enforced by either zoning or contract with the state. In the 1985 state budget, a mandate was adopted to integrate farmland preservation with soil conservation. Under the new scheme, a farmer must provide certification from the county Land Conservation Committee showing compliance with soil erosion standards before the zoning administrator can authorize the farmer's tax credit. This example of linking the carrots of tax incentives with the sticks of environmental regulation offers a powerful tool which might assist in the implementation of other programs as well (Sullivan *et al.*, 1985a,b).

The 1985 Federal Food Securities Act also included provisions to restrict tillage of marginal farmland: the "Sodbuster" provision addresses highly erodible lands, and the "Swampbuster" provision addresses drainage of wetlands. These provisions actually require the conservation districts to integrate resource information on soils with information on owners and land users who receive *any* federal farm program benefits. Because the integration which Congress intends is similar to the Wisconsin case, the Dane County Land Records Project provides an adequate demonstration that a multipurpose land information system can respond to these requirements efficiently and equitably.

DEVELOPMENT OF A MULTIPURPOSE LAND INFORMATION SYSTEM

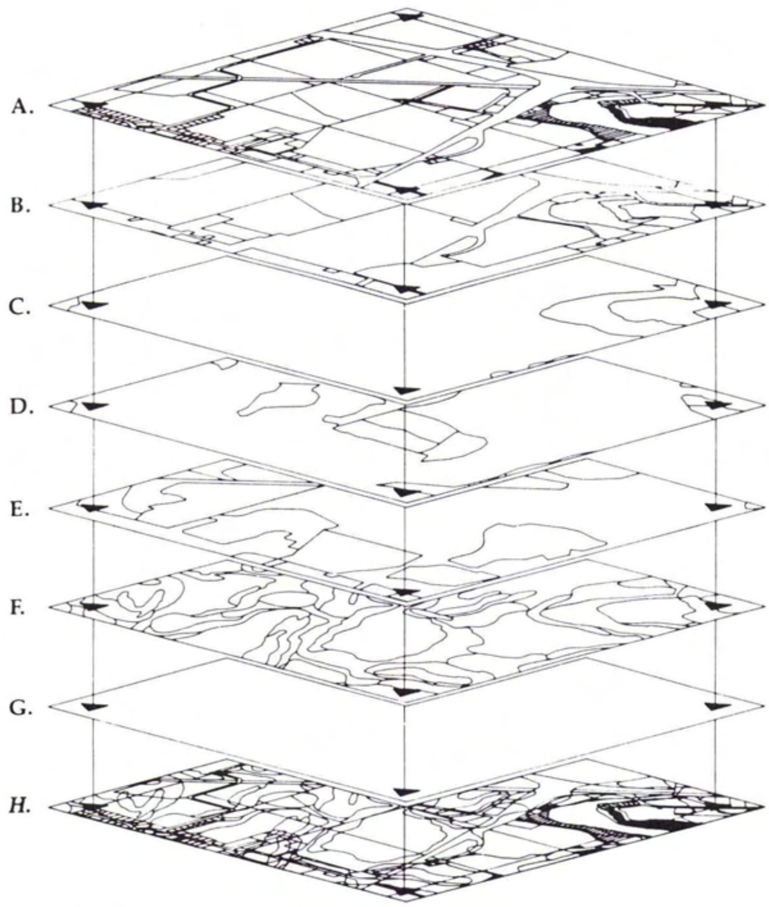
The Dane County Land Records Project (DCLRP) was established in 1983 by a cooperative agreement among the University of Wisconsin-Madison, Dane County, the USDA Soil Conservation Service (SCS), and the Wisconsin Department of Natural Resources. Other local, state, federal, and private cooperators subsequently became involved. The goal of the DCLRP was to demonstrate the utility of a multipurpose land information system for managing local land records, and for integrating these records for land planning.

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 53, No. 10, October 1987, pp. 1371–1378.

0099-1112/87/5310–1371$02.25/0

The DCLRP operated on a concept which included two primary components. First, the agency having the legal mandate to collect and store a particular set of spatial information should be responsible for maintaining its individual data layers in a digital form. Second, a mathematical reference framework should provide the linkage between individual layers (Chrisman *et al.*, 1984; Chrisman and Niemann, 1985) (see Figure 1). All of the layers shown were compiled in automated form for three study townships within the county (Westport, Oregon, Primrose).

ODYSSEY, a geoprocessing software system developed at Harvard and further extended at Wisconsin, was utilized to perform topological polygon overlay and other geographic analyses. The DCLRP investigated advanced geopositioning technologies, including both satellite and inertial systems. Digital remotely sensed



Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:	Responsible Agency:
A. Parcels	Surveyor, Dane County Land Regulation and Records Department.
B. Zoning	Zoning Administrator, Dane County Land Regulation and Records Department.
C. Floodplains	Zoning Administrator, Dane County Land Regulation and Records Department.
D. Wetlands	Wisconsin Department of Natural Resources.
E. Land Cover	Dane County Land Conservation Committee.
F. Soils	United States Department of Agriculture, Soil Conservation Service.
G. Reference Framework	Public Land Survey System corners with geodetic coordinates.
H. Composite Overlay	*Layers integrated as needed, example shows parcels, soils and reference framework.*

Land Information and Computer Graphics Facility,
College of Agricultural and Life Sciences, School of Natural Resources

UNIVERSITY OF WISCONSIN-MADISON

FIG. 1. Concept for a multipurpose land information system.

imagery was incorporated following classification and a vectorization process. In the implementation and use of a multipurpose land information system, order-of-magnitude improvements in efficiency are possible through use of geoprocessing, geopositioning, and remote sensing technologies.

Geoprocessing Software

Manual digitizing time for mylar soil sheets (1:15,840 scale, 7 square miles, average 300 polygons), combined with editing time (including automated error checking) to produce a topologically clean sheet, averaged 12 hours per sheet (Chrisman, 1986b; Green and Moyer, 1985). The Wisconsin SCS office subsequently obtained a low cost scanner which incorporated a digital camera. The adoption of scanning digitizing was found to reduce combined digitizing and editing time to 4 hours per sheet (Chrisman, 1986a).

A photogrammetric technique for removing relief distortion from rectified photobases, using U.S. Geological Survey (USGS) digital elevation models, was developed (Barnes and Vonderohe, 1985). A "zipping" process was developed to automate the edgematching of separately compiled map sheets, using both spatial and topological information (Beard and Chrisman, 1986).

Research was also undertaken to develop empirical techniques for specifying data quality, as recommended in the draft standard of the National Committee for Digital Cartographic Data Standards. This included documentation of lineage, positional accuracy, attribute accuracy, logical consistency, and completeness for USGS digital line graphs (Vonderohe and Chrisman, 1985; Ventura *et al.*, 1986a) and soils maps (Chrisman, 1986b).

Satellite Geopositioning

After digitization, individual map sheets were transformed to state plane coordinates (SPC) using section corners and quarter section corners for control. Establishment of SPC for the Public Land Survey System (PLSS) monuments involved tests and comparisons of traditional manual surveying techniques, and inertial and satellite geopositioning technologies (Vonderohe and Mezera, 1984; Vonderohe *et al.*, 1985; von Meyer *et al.*, 1985). These tests demonstrated an order of magnitude difference in both time and cost for these methods of establishing the reference framework. Whereas manual surveying methods required several days and thousands of dollars to establish coordinates for a point, Global Positioning System satellite methods required only a few hours and hundreds of dollars.

Remote Sensing

In conjunction with the University of Wisconsin Environmental Remote Sensing Center, the DCLRP acquired, classified, and vectorized Landsat Thematic Mapper data for agricultural lands in Dane County (Ventura *et al.*, 1985, 1986b). Classes were aggregated to obtain those required for the soil erosion planning process: row crops, hay/meadow, woods, water, other. These data were subsequently combined with additional data sets: digital wetlands maps produced by the Wisconsin Department of Natural Resources (1:24,000 scale), and USGS municipal boundary digital line graphs (DLGs) for exclusion of incorporated areas (also 1:24,000 scale). The vector format land-cover map, derived from TM imagery, digital wetlands data, and DLGs, was compared through topological overlay analysis with the manually derived land-cover map. The comparison indicated that the digitally-derived land-cover map was an adequate source of *C* factor (cropping practices) information. It was then utilized to determine *C* factor information on a county-wide basis. Additional research is necessary to investigate the utility of digital land records in vector form, such as field boundaries, to assist in developing scene stratification and per-field image classifiers.

Again, an order of magnitude time difference was found: approximately ½ hour per PLSS section was required for traditional manual photointerpretation of Agricultural Stabilization and Conservation Service (ASCS) 35-mm slides and compilation on the SCS soils photobase, but only a few minutes per PLSS section were needed to perform the digital classification.

MODELING SOIL EROSION POTENTIAL FOR EACH LANDOWNER

The Wisconsin soil erosion statute specifies the Universal Soil Loss Equation (USLE) as a means to predict soil loss on agricultural parcels (Wischmeier and Smith, 1978): i.e.,

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \tag{1}$$

where

A: Potential Soil Erosion (tons/acre/year)
R: Precipitation Factor
K: Soil Erodibility Factor
L: Length of Slope Factor
S: Steepness of Slope Factor
C: Cropping Practices Factor
P: Management Practices Factor

RESULTS

The accompanying maps portray the analysis of soil erosion potential for each landowner in the Town of Oregon, Dane County, Wisconsin, T5N, R9E, 4th Principal Meridian (Chrisman *et al.*, 1986a,b). Figure 2 was produced by a sequence of steps. Thirty-six tax parcel section maps maintained by the County Surveyor (1:4800 scale), most on linen bases drafted over 40 years ago, were manually digitized using a spaghetti method (Chrisman, 1986a). Topological structuring was performed automatically through ODYSSEY. After editing and automated edgematching, each tax parcel polygon was assigned its unique identifier, as recorded on maps maintained by the County Zoning Administrator. The identifier permitted access to the tax parcel assessment classifications recorded in the automated tax rolls of the County Tax Lister. Those parcels with an agricultural assessment classification are shaded in Figure 2.

The soils map in Figure 3 was produced by digitizing, editing, and edgematching six sheets from the Dane County Soil Survey (1:15,840 scale). Particular advantages were gained from using automated checks for topological consistency, which detected unlabeled polygons, missing linework, and edge misclassifications. After "zipping" together contiguous sheets, a topologically clean coverage was available.

Several soil mapping unit attributes were essential to the soil erosion estimation process. The *K* factor, or soil erodibility, is shown in Figure 3. The *LS* factor, or combined slope length and steepness factor (see discussion below), is not shown. Tolerable soil loss in tons/acre/year, the *T* value, is compared to the *A* value, potential soil erosion, which was calculated using the USLE. Other research, not reported here, is examining the reliability of *K*, *L*, and *S* factors determined by alternative methods: in-field procedures; derived attributes from soil mapping units; and processing of USGS 7.5-minute 30-m digital elevation models.

The land-cover map in Figure 4 was produced by digitizing, editing, and edgematching six sheets of land-cover maps prepared by the County Land Conservation Committee. These sheets were prepared by photointerpretation of 35-mm color slides obtained from ASCS, and compiling the data on the same photobase as the SCS soil sheets. The cooperator fields shown on this map are areas covered by agreements between the Land Conservation Committee and landowners. For each field, detailed USLE parameter values were determined and used in the soil loss calculations. Row crops and meadows were assigned approximate *C* factors by the County Land Conservationist, because crop histories were not available. Areas of woods and other cover types were excluded from the analysis.

The rainfall factor, *R*, is a constant for this study area. The management practices factor, *P*, is only known in the few cooperator fields shown on the land-cover map. On a county-wide

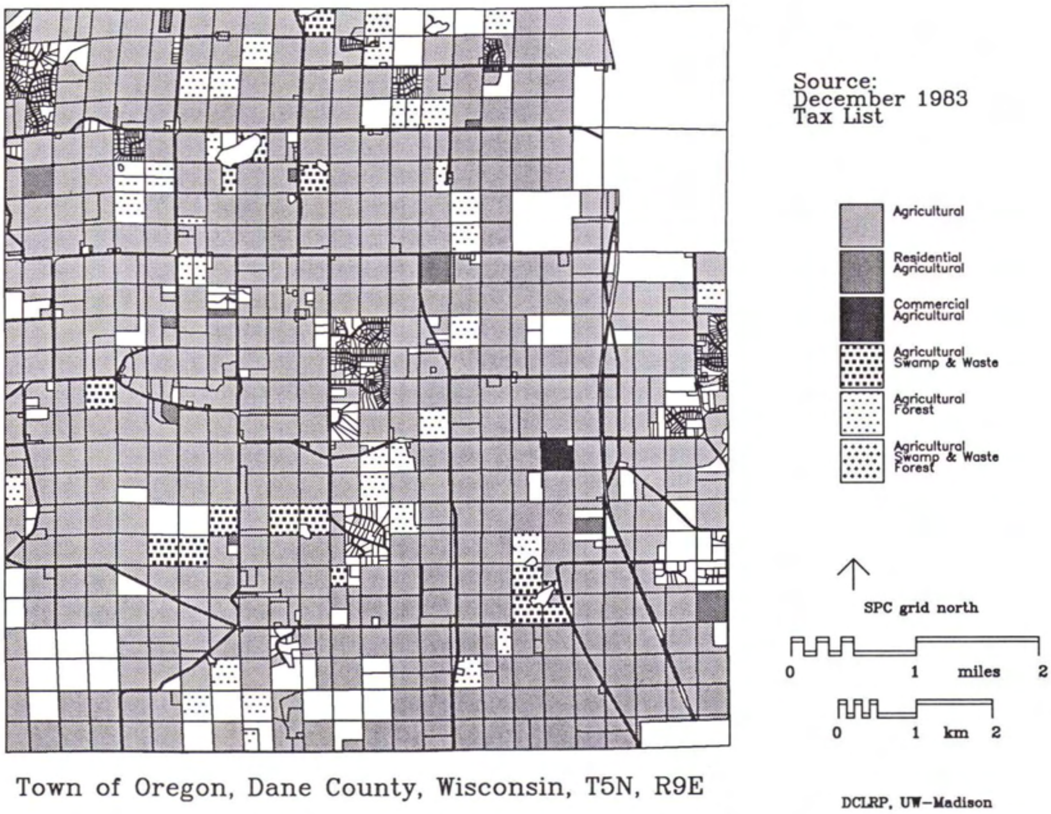


FIG. 2. Tax parcel assessment classifications.

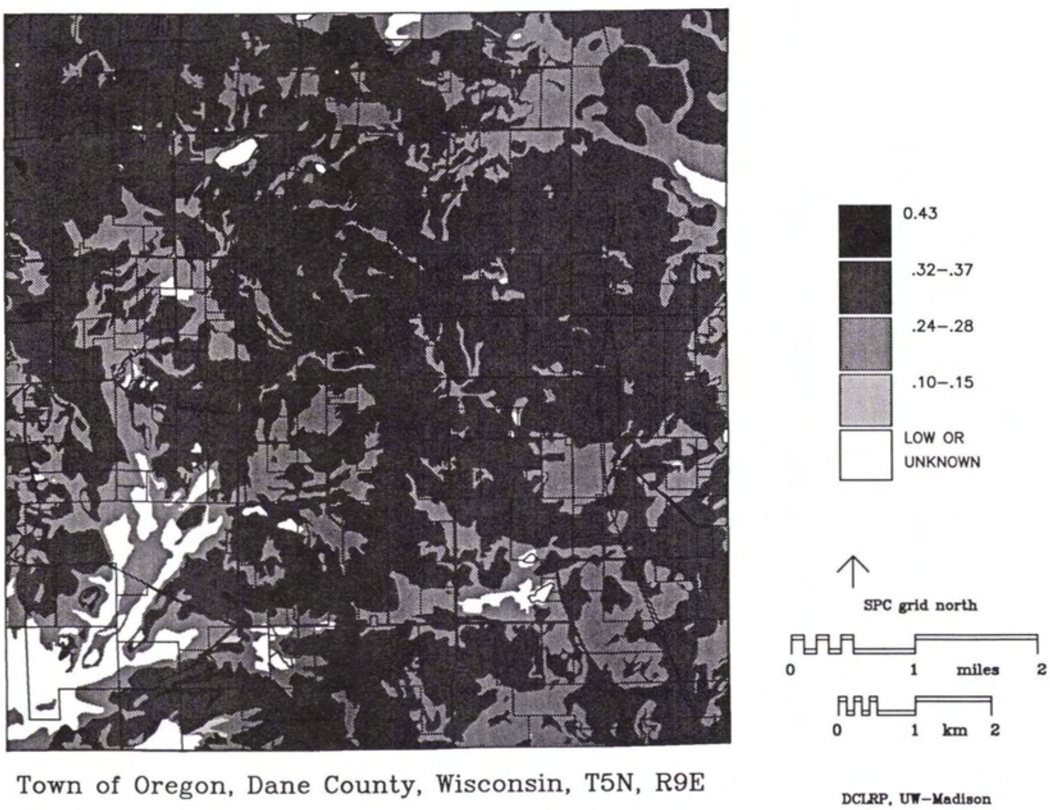


FIG. 3. Soil erodibility, *K* factor, by soil mapping unit.

basis, the management practices factor was derived from remotely sensed imagery and airphoto interpretation.

Figure 5 illustrates the analytical result obtained by overlaying the erodibility (Figure 3), slope (not shown), and land-cover maps (Figure 4), excluding non-agricultural areas (Figure 2), and calculating the *A* value from the USLE. The ratio of *A* to *T*

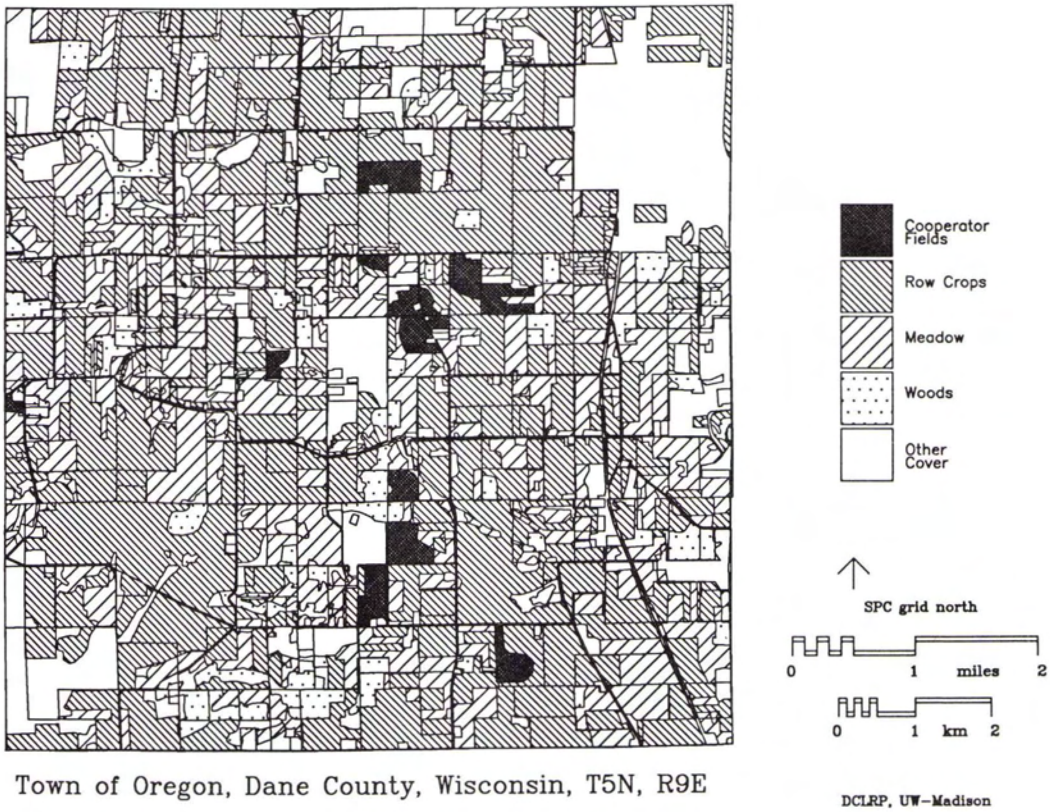


FIG. 4. Land cover, *C* factor, by field.

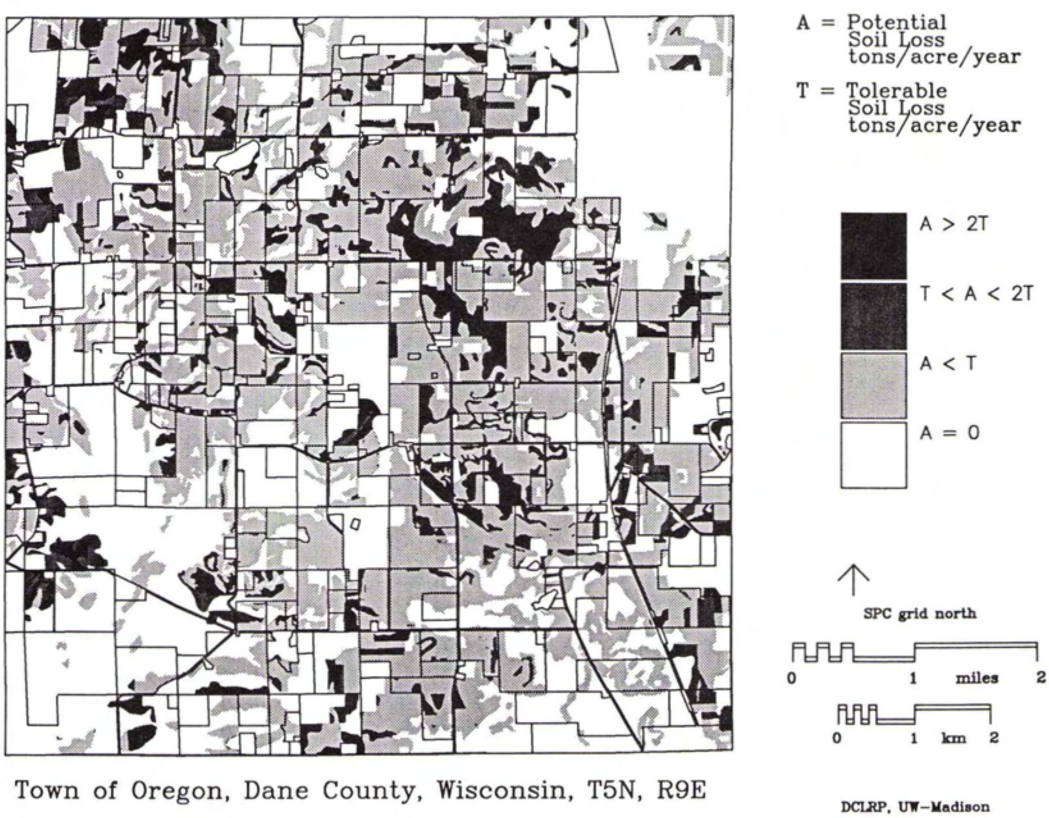


FIG. 5. Ratio of *A* to *T* for agricultural areas.

is shown in relation to the legislatively specified thresholds for targeting specific areas of potential erosion.

The average ratio of A to T was computed for whole units of landownership by area-weighted calculations restricted to individual fields. Figure 6 illustrates which parcels and landowners will not be in compliance ($A > 2T$ and $T < A < 2T$), without employing some additional conservation management procedures. Figure 7 illustrates the impact on soil erosion potential of employing conservation tillage practices. Nearly all parcels are brought below the level of $2T$, and many of those with moderate erosion potential are brought within the acceptable level ($A < T$) and no longer exceed tolerable soil loss. Eventually, an erosion control plan consists of altering cropping and management (C and P) practices to achieve compliance.

The use of an automated system for overlay and analysis of map layers provided the County Land Conservation staff with a workable method for prioritizing their field observations and landowners contacts as they work to implement the soil erosion control plan. Whereas a manual overlay analysis for a township might take days (although it would likely not be attempted), the same analysis can be performed in an hour with the automated system. Similarly, a manual interpretation of an individual farm's eligibility for a given program often required hours, while the computer-assisted interpretation requires only minutes per farm. Through development of automated case files and linkage to the digital layers of land information, the County Land Conservation staff is moving toward a viable system for monitoring compliance.

MODERNIZATION PRINCIPLES DERIVED FROM THE DANE COUNTY LAND RECORDS PROJECT EXPERIENCE

A number of social, economic, institutional, and technological trends have been identified in the process of addressing modernization issues. Taking advantage of new land records and information technology requires educational and institutional change. In bringing about modernization, the following principles for the development and implementation of modern, multipurpose land information systems (LIS) need attention:

AUTOMATION

An LIS should be based upon concepts such as topological vector data structures, in which spatial locations, attributes, and their relationships (i.e., adjacency and connectivity) can be maintained; logical and spatial searches can be conducted; and cross-checking of consistency and closure, and unique identification of areas and attributes, are possible.

An LIS should support both spatial and attribute analytical capabilities such as topological polygon overlay, buffer generation, aggregation, and disaggregation.

An LIS should accomodate data capture from diverse land record sources, such as survey control, tax parcel maps, assessment records, zoning maps, soil maps, floodplain maps, wetlands maps, and airphotos and other remotely sensed imagery.

An LIS should support data conversions, such as raster-to-vector and vector-to-raster.

GEOPOSITIONING

An LIS should be constructed upon a geodetic reference framework, because spatial registration forms the basis for the analytical methods.

An LIS should be based upon remonumentation and determination of coordinates for Public Land Survey System (PLSS) corners (or equivalent survey monuments in non-PLSS areas) to provide both a spatial reference system and an improved legal system for property description.

Applicable standards should be established for geopositioning activities in support of land records modernization efforts.

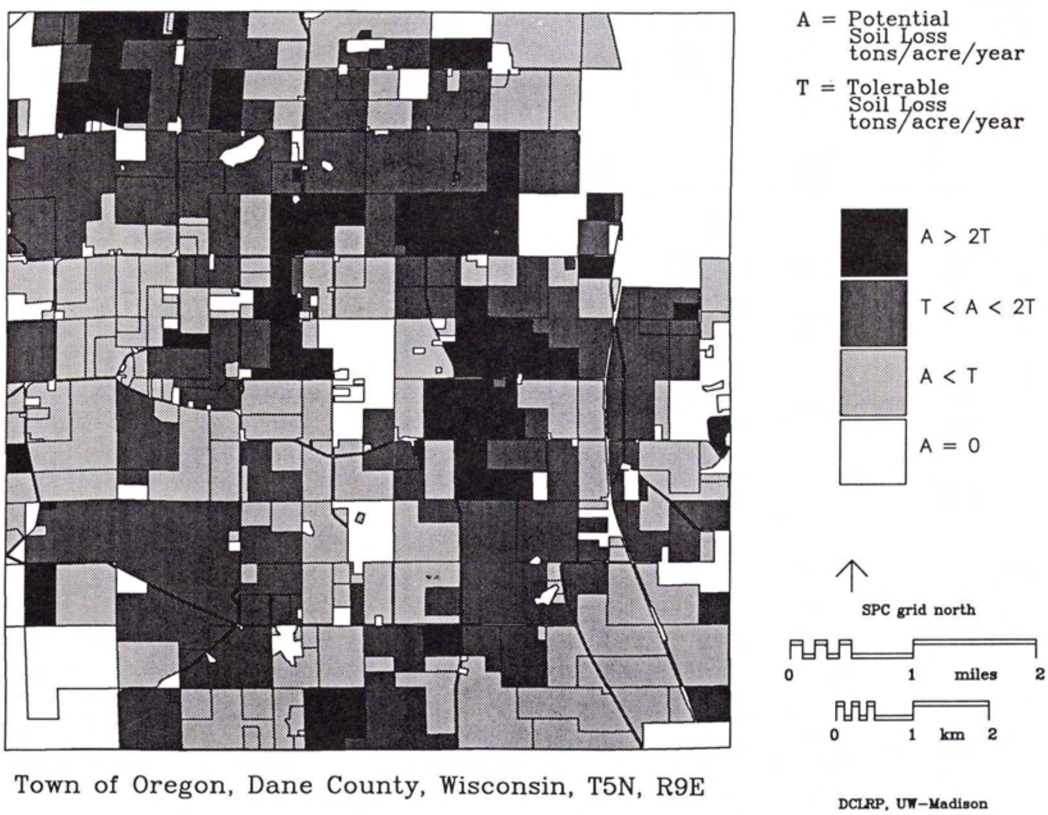


FIG. 6. A/T weighted by agricultural area, aggregated by landowner.

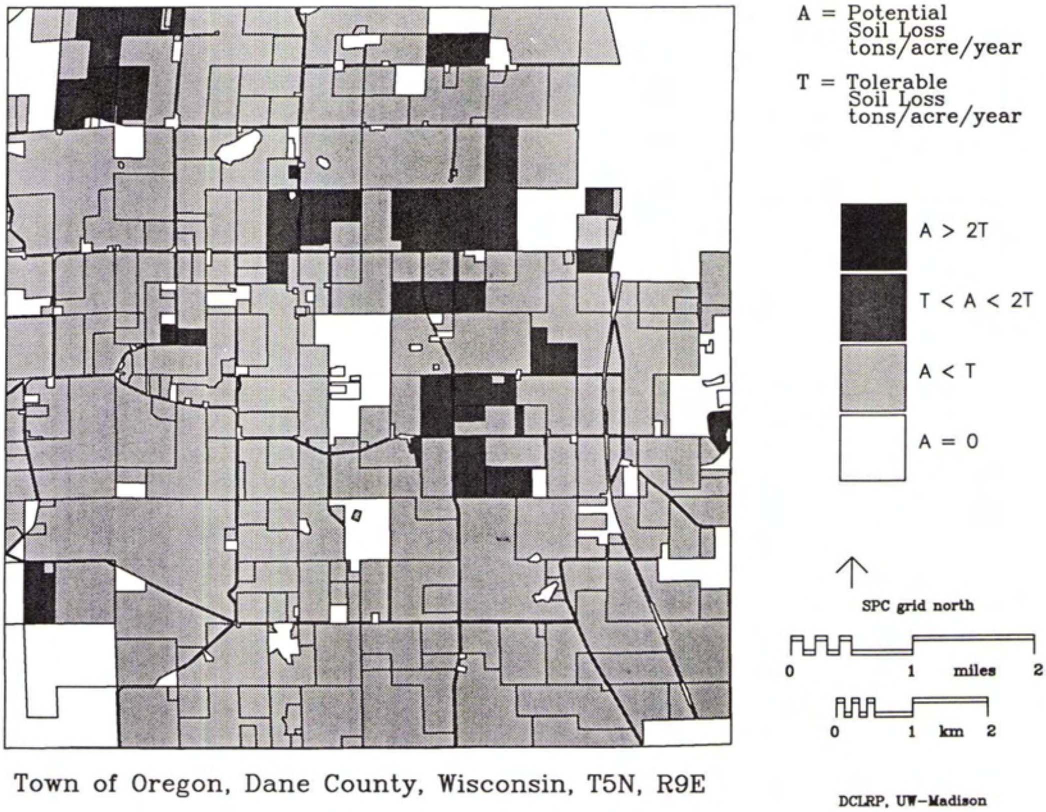


FIG. 7. Effects of adopting conservation tillage.

APPLICATIONS

An LIS should be multi-layered, including both legal and resource layers, such as property descriptors, tax assessment parcel records, unique parcel identifiers, soils, wetlands, and floodplains.

LIS implementation is a long-term venture and investment, and will require continuous monitoring rather than merely a one-time evaluation. However, a pilot project should be included to test and demonstrate high-visibility applications and provide output examples early on in the implementation process.

QUALITY

Records should be automated at the greatest available detail to assure non-degradation of original positional and attribute accuracy; thereafter, aggregations should be performed for more general applications.

Standards should be developed and adopted for encoding and exchange of each layer, including property, resource mapping, remonumentation, and geodetic control.

An LIS should include procedures which clearly document the source, lineage (original scale, accuracy), and method of automation for each land record.

No single geographic unit, such as a parcel, will suffice for capturing information from other layers, such as resource polygons.

INSTITUTIONAL

LIS implementation should focus initially on institutional cooperation while also addressing technical issues.

LIS implementation should determine short-term and long-term custodial mandates and assign responsibilities for each layer in the system to insure continual maintenance.

Because the land records problem is interdisciplinary, an array of disciplines and professionals should be involved in the initial system development and planning stages.

LIS designers should ensure that the records base is politically unbiased, and broadly accessible for both daily management and policy-making functions. The record base must allow for efficient, comprehensive, and exhaustive analyses to insure fair and equitable treatment for all concerned.

ECONOMICS

New technologies should be incorporated into the operational LIS, such as the Global Positioning System and scanning, to gain needed efficiencies in geopositioning and digital conversion of land records.

Some applications and analyses will be accomplished much faster then formerly, while other applications which were not possible will emerge, and unanticipated benefits will result.

A learning curve exists in system development and use. Initial costs to convert and use records will be high until experience with the LIS has been gained.

CONCLUSION

In this evaluation of a multipurpose land information system, the DCLRP has demonstrated that it is technically feasible to identify land ownership parcels where soil erosion standards are not being met. The utility of combining advanced geoprocessing, geopositioning, and remote sensing technologies has been demonstrated. The needs for flexible data models, such as custodian maintained layers, and analytical procedures, such as topological polygon overlay, have also been demonstrated to respond to new land management questions and mandates such as cross-compliance. Further, major institutional factors that impact these issues have been documented.

There is legislative interest at both the state and national levels to ensure that society receives equitable returns upon public investments in support of agriculture. As a result, farm supports of various kinds are being linked to reduction in soil erosion and minimization of wetlands conversion. As public awareness of the need for better land management becomes tied to broader concerns, there will be increased needs to integrate diverse information, such as the natural resource and ownership layers used for the Wisconsin soil erosion plan.

It is possible that these technologies will have a similar social impact as the automation of the U.S. Census had upon the implementation of social policy in an earlier period. The ability to establish defensible indices of social indicators, based upon manipulation of the automated Census records, made it possible to form the information base that made desegregation an achievable goal. With the advent of modern information concepts and technologies which allow for merger of various records sets, are we at the brink of such an impact on rural land management? Will the application of such technologies provide sufficient certainty to allow legislative mandates for land management programs implemented at the parcel level? If so, this could have profound impacts on those who own and manage rural America.

ACKNOWLEDGMENTS

This work was performed under a cooperative research agreement among the University of Wisconsin-Madison, Dane County, Wisconsin Department of Natural Resources, Wisconsin Department of Agriculture, Trade and Consumer Protection, and the USDA Soil Conservation Service. Additional support and/or assistance was provided by UW-Madison Environmental Remote Sensing Center, Wisconsin's University Industrial Research Foundation, National Geodetic Survey, U.S. Geological Survey, Bureau of Land Management, Wisconsin Department of Transportation, Wisconsin State Cartographer's Office, Madison Area Surveyors' Council, and Wisconsin Power and Light.

The co-principal investigators in the Dane County Land Records Project were N. Chrisman, D. Mezera, D. Moyer, B. Niemann, and A. Vonderohe. Research assistants were G. Barnes, K. Beard, K. Cotter, M. Dawood, C. Ghilani, J. Green, B. Gurda, D. Krohn, J. LaVerriere, N. MacGaffey, G. Mahun, J. Sonza-Novera, J. Sullivan, M. Thoma, S. Ventura, and N. von Meyer. Thanks to cooperators K. Connors, R. Martin, M. Riggle, J. Ujke, and many others unmentioned.

REFERENCES

Barnes, G., and A. P. Vonderohe, 1985. An Analytical Technique to Account for Photographic Distortions in Natural Resource Records. *Proc. URISA*, Denver, 1:171–180.

Beard, M. K., and N. R. Chrisman, 1986. Zipping: New Software for Merging Map Sheets, *Proc. ACSM*, 1:153–161.

Chrisman, N. R., 1986a. Effective Digitizing: Advances in Software and Hardware, *Proc. ACSM*, 1:162–171.

———, 1986b. Quality Report for Dane County Soil Survey Digital Files. *Report 7, NCDCDS* (H. Moellcring, ed.), Columbus, Ohio, pp. 78–88.

Chrisman, N. R, D. F. Mezera, D. D. Moyer, B. J. Niemann, J. G. Sullivan, and A. P. Vonderohe, 1986a. Soil Erosion Planning in Wisconsin: An Application and Evaluation of a Multipurpose Land Information System. *Proc. ACSM*, Washington, D.C., 3:240–249; also presented at FIG, Toronto, Ontario.

———, 1986b. Soil Erosion Planning in Wisconsin: Order of Magnitude Implications of Integrating New Technologies. *Proc. URISA*, Denver, 1:117–128.

Chrisman, N. R., D. F. Mezera, D. D. Moyer, B. J. Niemann, and A. P. Vonderohe, 1984. *Modernization of Routine Land Records in Dane County, Wisconsin: Implications to Rural Landscape Assessment and Planning*. URISA Prof. Paper 84–1. 44 p.

Chrisman, N. R., and B. J. Niemann, 1985. Alternative Routes to a Multipurpose Cadastre: Merging Institutional and Technical Reasoning. *Proc. Auto-Carto 7*, Washington, D.C., pp. 84–94.

Green, J., and D. D. Moyer, 1985. Implementation Costs of a Multipurpose County Land Information System. *Proc. URISA*, Ottawa, 1:145–151.

Sullivan, J. G., B. J. Niemann, N. R. Chrisman, D. D. Moyer, A. P. Vonderohe, and D. F. Mezera, 1985a. Institutional Reform Before Automation: The Foundation for Modernizing Land Records Systems. *Proc. ACSM*, Washington, D.C., pp. 116–125; also presented at the FIG International Symposium: The Decision Maker and Land Information, Edmonton, Alberta, pp. 383–391.

Sullivan, J. G., N. R. Chrisman, and B. J. Niemann, 1985b. Wastelands vs. Wetlands in Westport Township, Wisconsin. *Proc. URISA*, Ottawa, 1:73–85.

Ventura, S. J., N. R. Chrisman, and A. P. Vonderohe, 1986a. *Quality Analysis of Digital Line Graph Data for the Dane County Land Records Project*. Dane County Land Records Project, University of Wisconsin-Madison, 22 p.

Ventura, S. J., B. J. Niemann, and T. M. Lillesand., 1985. Land Cover for Soil Erosion Control Planning from Landsat Thematic Mapper Data. *Proc. URISA*, Ottawa, 1:86–95.

Ventura, S. J., J. G. Sullivan, and N. R. Chrisman, 1986b. Vectorization of Landsat TM Land Cover Classification Data. *Proc. URISA*, Denver, 1:129–140.

Vonderohe, A. P., and N. R. Chrisman, 1985. Tests to Establish the Quality of Digital Cartographic Data: Some Examples from the Dane County Land Records Project. *Proc. Auto-Carto 7*, Washington, D.C., pp. 552-559.

Vonderohe, A. P., and D. F. Mezera, 1984. A Cooperative Venture: Dane County Doppler Survey. *Proc. ACSM Fall Meeting*, San Antonio, TX, pp. 395–401.

Vonderohe, A. P., D. F. Mezera, and N. R. von Meyer, 1985. Geopositioning Experiences at the University of Wisconsin - Madison. *Proc. URISA*, Ottawa, 1:152–64.

von Meyer, N. R., D. K. Krohn, D. F. Mezera, and A. P. Vonderohe, 1985. Dane County Inertial Surveying Experiment. *Proc. ACSM*, Indianapolis, pp. 239–248.

Wischmeier, W. H., and D. D. Smith, 1978. *Predicting Rainfall Erosion Losses - A Guide to Conservation Planning*. USDA Agricultural Handbook 537.

Wisconsin Administrative Rules, Chapter Ag 160: Soil Erosion Control program (1984).

Wisconsin Statutes, Chapter 92: Soil and Water Conservation (1981).