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LAND EVALUATION AT FARM LEVEL USING SOIL SURVEY INFORMATION SYSTEMS

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Summary

County soil surveys of the United States National Cooperative Soil Survey program include detailed soil maps, soil descriptions, soil characteristics, and various soil interpretations. This information can be used for a variety of applications including land evaluation at the farm level. In Minnesota, a user-friendly and menu-driven soil survey information system (SSIS) was developed to help users access the information very easily and quickly for land assessment, farm management, land use planning, soil conservation programs, and education. Application software using the SSIS soil map database was developed for specific uses. PRODEX software is a tool developed for land evaluation. It evaluates relative productivity potential of land parcels using the Crop Equivalent Rating (CER). A soil survey information system can also help evaluate soil conditions for farming by soil. Conventional agricultural management uses one fertilizer and pesticide application rate for an entire field based on a single yield goal determined by dominant soil and climatic conditions. This management creates inefficiencies in application and product effectiveness by overtreating or undertreating some areas. This results in increased field management costs and the potential for surface and ground water pollution. County detailed soil surveys used with emerging modeling techniques, remote sensing technologies, geographic information systems, and computerized field applicators offer great opportunities for farming soil more efficiently in the agricultural ecosystem.

Introduction

Minnesota, and most agricultural lands of the United States of America will have a detailed soil survey by 1990. The objective of the National Cooperative Soil Survey (NCSS) program is to obtain through soil surveys, an inventory of the Nation's soil resources, record the location of soils, predict soil performance under defined use and management, facilitate the transfer of soil information from one location to another, and contribute to the knowledge, understanding, and proper use of our land resources (U.S.D.A., 1988). Initially, soil surveys had as objectives not only to identify, classify and map soils but also to interpret them for various applications. Emphasis was on using detailed soil maps for their practical predictive values for farming, ranching, and forestry (U.S.D.A., 1984). Later, the use of soil survey progressively increased and new, more specific, or broader interpretations were added for engineering, soil conservation, residential and industrial developments, and land appraisal. Soil use predictions usually give a soil limitation ranking such a slight, moderate, severe.

Although soil surveys can be developed for one specific purpose, they are normally made to cover a broad range of interests and needs. They are used for farm management as well as land-use planning. Modern detailed soil surveys made for counties with predominant agricultural land use have common scales of 1:15840 or 1:20000. This is a compromise between the level of details needed for intensive land use and farm management, and the cost of mapping. This level of mapping is termed a second order survey. It is made for intensive land uses that require detailed information about soil resources for making predictions of soil suitability and management. The information can be used in planning for general agriculture, construction, urban development and similar uses that require precise knowledge of the soils and their variability (U.S.D.A., 1984). Map unit delineations on soil maps represent areas dominated by one major kind of soil or several kinds of soils. A map unit is identified and named according to the taxonomic classification of the dominant soil or soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, soils generally have a great variability in their properties. Consequently, every map unit has soils that belong to other taxonomic classes. These occupy small areas (1.5 to 10 acres, 0.6 to 4 hectares depending on survey scale) and cannot be shown separately on the soil maps at the selected mapping scale. They are called inclusions and are always noted in the map unit description (U.S.D.A., 1985). This is very important to emphasize when using soil surveys for land evaluation.

The county soil survey report is then commonly a large technical document with much information. The report is difficult to use by non-technical users, limiting utilization of the information. A few years ago the Minnesota Cooperative Soil Survey started a program to make county detailed soil surveys readily and easily accessible to users for a variety of applications at a farm level.

Soil Survey Information System

The Soil Survey Information System (SSIS) is a computerized county detailed soil survey (Robert & Anderson, 1987). SSIS can retrieve, sort, display, highlight, and print any soil survey data for an area of one section (1 mi^2, 640A, 259 ha) or a similar gridded area (e.g., 5000 ft^2 or 500 m^2 grid). SSIS, developed by the Department of Soil Science, University of Minnesota, has the following major objectives:

1. to provide easy, fast access to any soil geographic information (map, descriptions, characteristics, and interpretations) related to any tract of land. The software is truly user-friendly and menu-driven. Only a very limited training is needed for inexperienced microcomputer users.

2. to run on simple, inexpensive, and stand-alone microcomputer systems so that anyone can use SSIS anywhere, in any office, home or field, and anytime for day-to-day decision making.

3. to create a versatile system for easy and quick update of maps and data, addition of new soil interpretations for urban, rural and forest uses, and overlay of other geographic data bases.

4. to provide a base for the development of specific application

software using selected data of the information system. The software is user-friendly and menu-driven (Fig. 1). This is a prerequisite for software used in field, county offices, and on farms by users with very little computer experience.

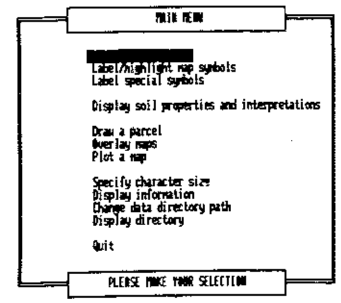


Fig. 1. SSIS MAIN MENU

Options are clearly presented and selected by pressing a few keys. Menus have pop-up HELP screens to assist in making selections. The computer program has routines to check menu selections and data entries. When an error is detected, a message indicates the correct procedure or the expected input. INFORMATION screens are provided upon request to define soil terms and procedures, to explain how the data were collected and analyzed and to specify data limitations for specific applications. A user guide is provided to configurate the software to the hardware. The system displays the soil survey data. The map unit soil symbols can be shown or highlighted (Fig. 2).

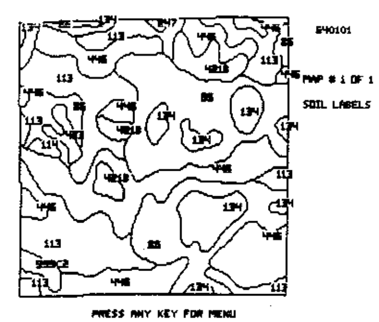


Fig. 2. SSIS Soil map with symbols

A summary table describes each symbol. For example, the soil symbol 86 is described as Canisteo clay loam and 421B is described as Ves loam, 1 to 4 percent slopes. SSIS can highlight soil features in color, e.g., all soil map units with soil reaction greater than 8 and give a corresponding total acreage (Fig. 3).

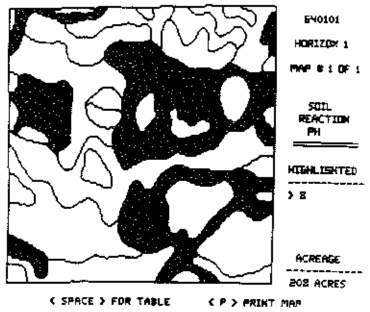


Fig. 3. Interpretive map showing map units with soil reaction greater than 8.

The soil properties and interpretations available with the current version (2.0) of the Redwood County SSIS are:

- Crop and pasture expected yields, soil productivity index (PRODEX), and prime farm land;

- Building site development;

- Construction materials;

- Water management;

- Sanitary facilities;

- Recreational site development;

- Wildlife habitat potential;

- Engineering properties;

- Soil and water features;

- Physical and chemical properties.

Each category has several options. For example, the Sanitary facilities submenu gives soil limitations for:

- Septic tank absorption fields;

- Sewage lagoon areas;

- Sanitary landfills - trench
  - area
  - daily cover

A new category - Ground water pollution susceptibility for nitrogen and some common pesticides - will be added soon.

The MAIN MENU has the option "Draw a parcel" to delineate a parcel of land using the arrow keys on the keypad or using a small digitizing tablet. In both cases, a menu displays options to draw straight lines between selected points, to draw continuously irregular lines, to correct and erase lines, to mask all features outside the parcel. The "Plot a map" option provides a submenu to plot a map at a selected scale. The system can also display and overlay other digitized maps such as land use, ownership, vegetation cover, roads, drainage, etc. A separate overlay routine, the Map Overlay System (MOS), displays in color the location of overlapping features selected from two different types of maps and calculates the acreage of combined attributes. A spreadsheet type screen shows the acreage of all possible combinations.

The Soil Survey Information System runs on IBM PC, PS/2 and compatibles with 512K RAM memory, two flexible disk drives or a combination of flexible drive(s) and firm disk drive(s), one graphics adapter and monitor (CGA, EGA, or VGA). A dot matrix printer, a desktop plotter, or a digitizing tablet are optional. SSIS works with digitized soil maps and optional overlay maps. The soil survey base map sheets on mylar are digitized using a high resolution scanner. Hand digitizing was found too slow, costly, and had the potential for considerable errors. Digitizing tablets are used to digitize simpler land features such as land use, cover types, and ownership parcels.

According to a recent survey (Finney & Paulson, 1986), the principal uses of the system were, in decreasing order, land appraisal, farm management, government and local programs, and education. The main uses of the software by county departments were for land assessment, federal and state conservation programs, and land use, planning, and zoning. On farms, the system is principally used to improve fertilizer and herbicide management (Ohm, 1985), select sites for soil sampling, design conservation plans, prepare cropping plans, and evaluate land for rental or purchase (Robert & Anderson, 1988). Extension agents are using SSIS to help farmers locate the most productive soils, to improve soil management (e.g., tillage and drainage) and crop management (e.g., agrichemicals) (Robert & Anderson, 1986). Maps of soil surface texture (Fig. 4), organic mater percentage, and pH levels are useful when selecting herbicide rates.

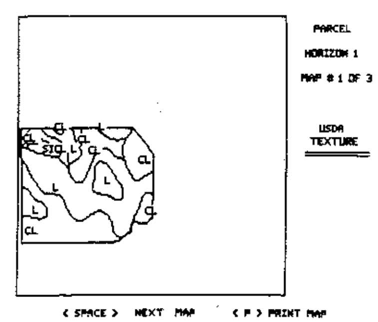


Fig. 4. USDA soil surface texture interpretive map (C: clay, CL: clay loam, L: loam, SICL: silty clay loam).

Several counties are using a land use overlay for land assessment, planning and zoning, and conservation programs. Four northern Minnesota counties have a forest cover overlay in progress for timber management.

Recently there has been a strong and growing interest in SSIS, as the use of the system has increased, from agribusinesses, agricultural cooperatives, appraisers, realtors and bankers. The SSIS data base is utilized in several application software packages developed for specific uses. The PRODEX software was developed for land appraisal and assessment.

PRODEX: land assessment for individual parcels.

County soil surveys provide detailed and unique information about the soil characteristics of land. Soil surveys can be interpreted specifically in terms of soil qualities that bear directly on soil potential productivity and land evaluation for assessment (U.S.D.A., 1984). One important attribute of soil survey is the fact that most soil characteristics do not change very much whereas other elements that determine the land value change with time. A land assessment index based on soil properties can easily be reinterpreted as economic or institutional conditions change.

A variety of productivity ratings have been developed to provide a common basis to compare one soil to another. Productivity comparisons are usually made for one or two levels of management. When used in combination with detailed soil surveys, potential productivity of soil mapping units or land parcels can be evaluated. Productivity ratings in general are numbers that reflect relative value of a soil for agricultural or forestry use (Miller, 1984). In many instances these ratings have been based on physical and chemical properties of soils and the effect that these properties have on productivity for the most commonly grown crops (Huddleston, 1982). In Minnesota, the productivity rating system that is used is the Crop Equivalent Rating (CER) (Rust et al., 1984). This system goes one step beyond relating soil properties to gross crop yields. Recognizing the importance of management in obtaining economic yields, the CER reflects the inputs necessary to obtain a given yield such as fertilizer, drainage, and irrigation. Therefore, net economic returns are calculated and indexed instead of just soil properties. CER's are indexed on a scale of 0 to 100. A relative ranking can be assigned to any soil of some extent.

The following procedures are used to provide the basis for equalized assessment:

1. data are obtained on the selling price, earning value, cash rent or appraised value of agricultural land in representative soil areas;

2. the relationship between the CER and one or more measures of dollar value are determined;

3. a schedule of adjustments for location of roads, special soil conditions, and other local conditions is prepared.

Adjustments can be made to the CER values for the following: lands

in pasture and timber, climate, drainage, and physical land constraints. A CER of about one third the cropland value is recommended where cultivated cropping is not a feasible alternative and the land is either in permanent pasture or timber production. Climatic adjustments are made on the basis of rainfall differences. If average rainfall of the county under consideration differs an inch or more from the geographical center of that soil, 3 percent is added to the CER for each additional inch of rainfall or subtracted for each inch of lower rainfall.

To relate the CER for specific soil survey mapping units to individual ownership parcels requires manipulation of large amounts of data. Before availability of microcomputers, this manipulation was done primarily by hand. This involved considerable time and effort on the part of individual county assessors and was a drawback to the use of CER's for land evaluation in the assessment process. For this reason computer software was developed to be used with the Soil Survey Information System (SSIS) to quickly and accurately assess relationships between land parcels and CER. This software, titled PRODEX (Productivity Index), also allows rapid changes and adjustments to both individual soil and parcel ratings.

The objectives of the software are to (Anderson & Robert, 1987):

1. allow the rapid use of detailed soil survey information to evaluate relative productivity potential of any size land parcel up to one section;

2. provide access to SSIS and evaluate the CERs for a parcel;

3. provide menu options to draw ownership parcels, change CERs for map units, and change the weighted average productivity rating;

4. print and/or save the results on disks.

The program operation of the PRODEX software is very simple. A detailed digitized soil survey map (one section) for the land parcel to be evaluated is first retrieved through menu options. An optional overlay grid of different sizes can be selected to assist in locating parcels. Land parcels can be drawn by two methods. Parcel boundaries can be drawn using the keyboard "arrow" keys or using a digitizing tablet. Once the land parcel has been identified, the rest of the soil map is masked to highlight parcel boundaries (Fig. 5).

Each soil map unit within the parcel is automatically measured to determine the number of acres according to the scale of the map. Soil series labels are then retrieved. Productivity ratings, in the form of the CER corresponding to each of the soil survey mapping units, are displayed in tabular form (Figure 6). A number code is assigned to each soil subarea on the map. Individual CERs are displayed by subarea with number of acres and weighted acreage CER value for the ownership parcel. The data can be changed and adjustments made to the CERs according to any previously prepared schedule of adjustments or as a result of any changes in total acreage.

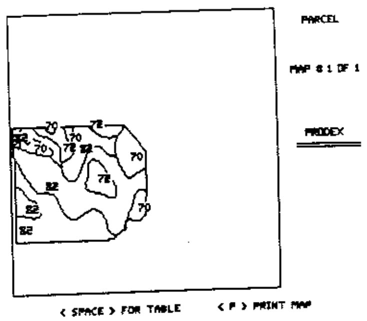
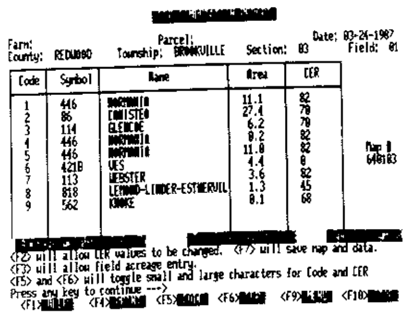


Fig. 5. Parcel boundary identified with each mapping unit CER value.



Farm:
County: REDWOOD Parcel: Township: BROOKVILLE Section: 03 Date: 03-24-1987 Field: 01

Code	Symbol	Name	Area	CER
1	446	NORMANIA	11.1	82
2	86	CANISTEO	27.4	78
3	114	GLENCOE	6.2	78
4	446	NORMANIA	0.2	82
5	446	NORMANIA	11.0	82
6	421B	WES	4.4	0
7	113	WEBSTER	3.6	82
8	818	LEMOND-LINDER-ESTHERVIL	1.3	45
9	562	KNOKE	0.1	68

Map # 640103

<F2> will allow CER values to be changed. <F7> will save map and data.
<F3> will allow field acreage entry.
<F5> and <F6> will toggle small and large characters for Code and CER
Press any key to continue --->
<F1> <F4> <F5> <F6> <F9> <F10>

Fig. 6. Tabular display of data for each map unit and weighted average productivity rating.

Applications of PRODEX are multiple. CERs can be used to evaluate productivity of different land parcels. This information can aid producers and planners to make management decisions. When used with the Soil Survey Information System, the area and distribution of each soil can be measured and an evaluation of productivity can be made for an individual soil map unit or as a weighted average for a parcel. Some areas of application are:

1. Land management. A general assessment of the quality of the soil resource managed can be made. CERs as an index based on net economic returns provide an independent, objective and quantitative method to evaluate productivity.

2. Land rental and purchase. Graphs can be constructed for various geographic regions by correlating bona fide sales data with soil CERs. The weighted average CER by parcel can then be calculated to determine a fair market value or, if rental values are used, a fair rental price.

3. Equalized assessment.

4. Preservation of agricultural land. Weighted average CERs provide an objective indicator of overall parcel quality. (Fig. 7). High CER values would indicate that the parcel is high quality agricultural land and it should be dedicated to agriculture. This, of course, cannot be the only criteria on which these decisions are made, but it is a useful tool.

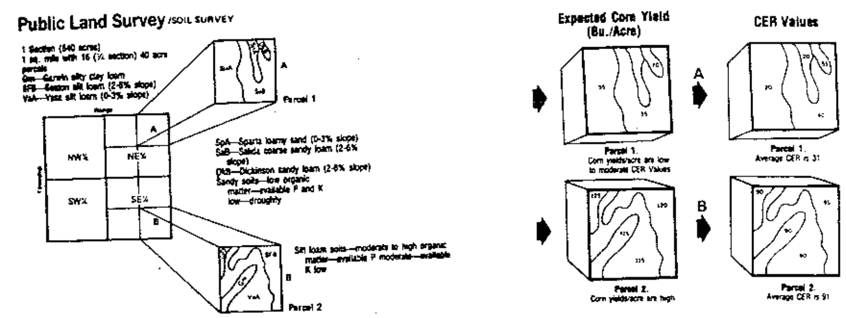


Fig. 7. Productivity ratings offer an objective method to evaluate parcel boundary.

PRODEX is an example of application software using the soil survey information system. A similar program was developed to evaluate parcel eligibility for state and federal conservation programs. Another program helps select locations and number of soil samples within fields to provide a good representation of soil variability. This software aids soil sampling for fertilizer recommendations. Development of this kind of software, used with a soil survey information system will continue to increase the use of soil survey information.

Land evaluation for soil specific farming.

A new application, at the farm level, of soil surveys and particularly soil survey information systems is farming by soil. Uniform field application of fertilizers, herbicides and seeds create inefficiencies by over-treating some soils and under-treating some others. This increases field management cost, decreases net return, and may contribute to surface and ground water pollution. County detailed soil surveys used with emerging modeling techniques, remote sensing technologies, computerized geographic information systems, and computerized field applicators offer great opportunities for farming soils more nearly according to their capabilities.

Detailed soil surveys or aerial photographs taken after plowing show that individual fields of any size have generally several different soil types (Robert & Rust, 1982). This varies with the type of landscape. Rolling moraine may have a much greater soil variability than flatter landscape developed from more homogenous parent material. In southwestern Minnesota, most fields have at least three contrasting soil types with variable texture, organic matter content, pH, available water-holding capacity, permeability, and nutrient content levels.

The following example comes from one 80 acre field in 1987 in Renville county, Minnesota.

	Soil type 1	Soil type 2	Soil type 3
Acreage (ha)	50 (20)	17 (6.8)	13 (5.2)
Soil characteristics			
O.M. (%)	6.3	3.2	2.2
pH	7.7	8.1	8.0
Nitrogen. lb/ac (kg/ha)	50 (56)	32 (35.8)	38 (42.5)
Phosphorus. lb/ac (kg/ha)	15 (16.8)	30 (33.6)	8 (9.0)
Potassium. lb/ac (kg.ha)	302 (338)	304 (340)	342 (383)
Zn (ppm)	1.7	.4	.4
Soil management			
Yield goal. bu/ac (kg/ha)	160 (10750)	140 (9406)	110 (7390)
Fertilizer recommendation (N-P-K)	155-95-50	135-50-40 (10 lb. Zn)	85-85-0 (10 lb. Zn)
Cost/acre (ha)	$50.45 (20.2)	$45.59 (18.2)	$37.74 (15)
Herbicide recommendation Lasso, qt. (L)	4 (3.8)	3.5 (3.3)	3 (2.8)
Cost/acre (ha)	$18 (7.2)	$16 (6.4)	$13 (5.2)

Benefits of farming by soil:

Increased yield: 7.6 bu./ac. x $1.65 =	$12.54
Herbicide cost saving	1.20
Fertilizer	-6.10
	$7.64 per acre ($3.06 per ha)

Soil survey information systems or application software can be used to group soil map units in classes of fertility levels (Fig. 8) and

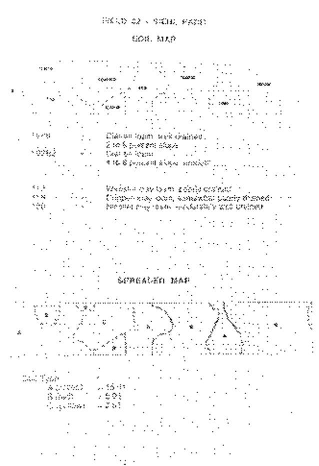


Fig. 8. Soil map and soil type spreader map of an experimental field (20 ac., 8 ha.) near the University of Minnesota SW Experiment Station.

create a field soil type map. When available, color infrared photographs can be combined with soil survey maps to increase the resolution of the field soil type map. When soil surveys and aerial photographs are not available, a systematic soil sampling can be used.

Kriging software is then used to create the field soil condition map using actual fertility levels. This technique is also preferred on coarse textured soils and on fields with some specific farming practices such as the use of manure. Fertilizer and herbicide recommendations are made for each soil condition (Fig. 9) instead of

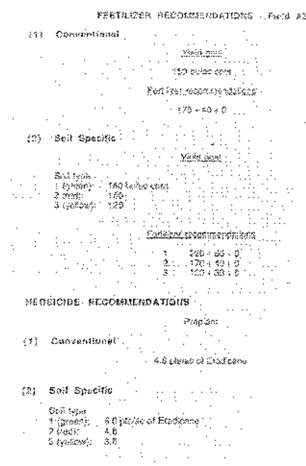


Fig. 9. Fertilizer recommendations for the Figure 8 field.

one recommendation for the field using conventional techniques. The soil type maps are digitized and read by a small microcomputer equipped with graphics and guidance capabilities installed in the cabin of a computerized spreader (Fig. 10, 11). When driving across a field, types and rates of fertilizers and chemicals are automatically selected as a function of soil types, or conditions.

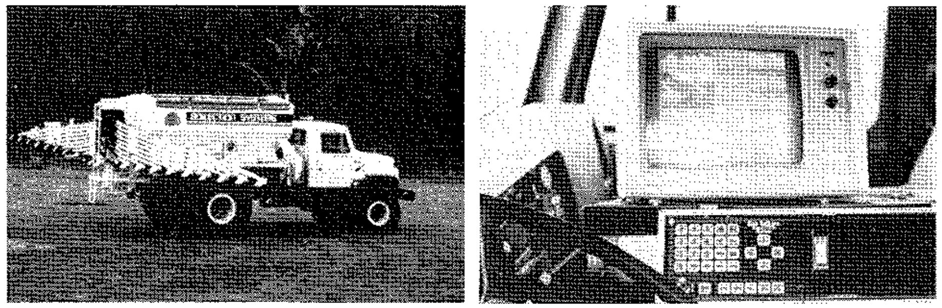


Fig. 10 and 11. Computerized spreader.

The benefits of new technologies of farming by soil are:

- Increase in farm profitability. Preliminary results indicate (current) improved net return by five to ten dollars per acre depending on field soil combinations. The improved net return is the result of more efficient fertilizer use, decreased herbicide cost, and increased yields.

- Optimization of soil productivity by selecting fertilizer rates and grades as a function of soil potential.

- Reduction in soil erosion by conserving or improving soil characteristics and fertility.

- Reduction in surface and ground water pollution by using rate of chemicals adapted to the soil conditions.

Conclusions

At this moment, the second order soil survey (county detailed soil survey) is generally adequate for farm management. In the future, there will be a need for larger scale soil surveys, for improved land evaluation, to optimize the use of new technologies such as farming by soil.

Acknowledgments

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