AN IMPROVED ECONOMIC LAND CLASSIFICATION SYSTEM FOR SPATIAL LINEAR PROGRAMMING MODELS

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Spatial linear programming studies in agriculture require establishment of a land resource base so representative enterprise budgets can be constructed to reflect productivity and limitations of each region's agricultural land. To relate the land base to budgeting procedures requires an economic classification of agricultural soils. Ideally, this classification would group together those soils requiring similar cultural practices and having the same yield capabilities. Costs and returns can then be computed for selected agricultural enterprises within each classification. Technical information on agronomically based soil classifications is available through agricultural experiment station reports and the Soil Conservation Service. These reports give an abundance of detailed physical and chemical soil data on a county basis.

Because technical data are extensive, a problem exists in translating this information into economic groupings suitable for use in constructing budgets. Economic classification of soils for a spatial study should be pragmatic but detailed enough to ensure a meaningful linkage of enterprise budgets to the soil.

This paper outlines an improved procedure for grouping agricultural land data for regional analyses. This procedure conforms more closely than other related groupings to the most current agronomic soil classification, and is flexible enough to be used in enterprise budget formulation for more than one specific region. The next section briefly evaluates soil delineation criteria reported in selected studies. A discussion of current soil classification in the United States is then presented, followed by the proposed method of using available land classification data to form agricultural land groupings appropriate for macroeconomic analyses.

SOIL CLASSIFICATIONS

Previous Economic Classifications

Whittlesey [15] used the land capability classes of the Conservation Needs Inventory (CNI) [11] to establish three soil quality classes for use in a spatial linear programming study containing 144 production regions. Eyvindson [1] used this same procedure in a later study.

The CNI is an ongoing national project to provide information on land use and conservation treatment needs on a county basis for each state, Puerto Rico and the Virgin Islands. Soil data are grouped into capability classes and then subclasses. There are eight capability classes which depict progressively greater limitations for agricultural production and fewer choices for cultivation. Subclasses indicate problems such as erosion or runoff, wetness and drainage, root zone and tillage limitations and climatic limitations [11].

The CNI provides consistent data across regions but presents difficulty in developing enterprise budgets, because detailed land use data and conservation treatment needs are available but no link to various soil types for a specific area is given.

In a later study, Nicol *et al.* [5] made commendable improvements toward an economic classification in a national spatial model. Basically, yields for the most productive land class in an area were defined. Ratios for each class were defined relative to these yields. These ratios were used in developing another set of ratios to relate land class to area average yields.

Shumway, *et al.* [9], in a spatial model for California, grouped soils into thirteen categories—four

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alluvial, five basin and four terrace soils with a description of typical soils in each category. This study used numerous sources in its classification as well as the help of area experts. To replicate their procedures would be difficult because they are more area-oriented and not general enough to expedite use in other regions.

The reviewed economic groupings are either too general for replication or have not made full use of available soil classification data that would enhance the separation of dryland versus irrigated yield and input configurations for enterprise budgeting. Several micro-oriented studies—Ramsey [7], in a Mississippi study, and Jobes [4] and Rathwell [8] in separate Oklahoma studies—are very detailed, but their major drawback is dependence on county soil survey data in which many are incomplete or nonexistent for other areas.

The United States Comprehensive Soil Classification System

In 1965, the United States National Cooperative Soil Survey implemented the Comprehensive Soil Classification System. This section gives a cursory view of this classification, since the following section uses technical soil information in presenting an economic grouping. Going from broadest to specific, the six categories of the system are as follows: order, suborder, great group, subgroup, family and series. Soil order reflect the variety of degrees of the soil-forming processes and major differences in soil genesis. Suborders of these become divisions that can be considered as a group. Characteristics which separate these subgroups include soil moisture, temperature and degree of decomposition of organic materials. Within each great group, a central concept is defined (for example, wetness). Great groups depict more homgeneity than previous classes and can be considered in more meaningful detail. Failure to precisely fit this central concept gives rise to subgroups. Families are then broken down from subgroups and are important for soil use, management and behavior. The lowest category, soil series, allows the most detail on a soil's characteristics and capabilities [12].

AN ECONOMIC CLASSIFICATION FOR REGIONS[1]

This section presents an alternative soil delineation scheme which better suits the needs of an ongoing spatial project for Oklahoma. As noted earlier, reviewed systems are not flexible enough for expeditious enterprise budgeting in other areas and do not conform to current soil delineations of agronomists. The proposed system provides adequate flexibility for addressing these problems.

The great groups of the Comprehensive Soil Classification System were chosen as the most useful delineation, since quantitative data on great groups allow a logical economic classification without the distraction of unnecessary detail. For example, of the 180 great groups in the United States, only 26 occur in Oklahoma. Using the great groups as the broadest category for classification, typical or benchmark soils can be used—these have been designated by the Cooperative Soil Survey as representative of each of the great groups [2, 13].[2] This provides the researcher with a direct link between a broad class, great groups, and the lowest category, soil series. From the soil series, one can construct enterprise budgets consistent with soil characteristics and management practices, and yield estimates can be made for various crops.[3] More detail in this linkage follows in a later section.

Given each great group and its representative soil series, use can be made of the capability groupings as defined by individual county soil surveys and the CNI. With these capability groupings, one can adjust yields on enterprise budgets to reflect the greater limitations in each progressive capability class, with representative soil providing the basis for these adjustments. As noted earlier, the CNI supplies the capability class for all counties in the United States. Since the early 1950s, the county soil surveys have included the capability class also.

To simplify capability levels, the eight classes were grouped into four as follows:

- Class I = land capability class I—few restrictions which limit use
- Class II = land capability class II—moderate restrictions which limit use
- Class III = land capability classes III and IV—severe to very severe limitations
- Class IV = land capability classes V-VIII—those suited primarily to pasture or woodland and wildlife and not generally used for cultivation.

Hence, the proposed system is composed of great

[1] Work accomplished in the Department of Agronomy at Oklahoma State University stimulated many ideas in this section. Discussions with Dr. Fenton Gray were especially helpful.

[2] Representative soils for seelected great groups should be available through Land Grant agronomy departments or obtainable through the Soil Conservation Service.

[3] Gray [2] has estimated the productivity on key soils of Oklahoma. These types of data are available through county soil surveys, experiment station bulletins and SCS offices. From county soil surveys, one can readily obtain dominant series for use as key soils.

groups, representative soil series and four defined capability classes. In contrast to several other proposed systems, this one can be used for any area of the United States. Data are relatively consistent across regional boundaries. Soil productivity and management can be associated within the delineation. As will be later discussed, data needs are not entirely dependent on incomplete county soil surveys. Also, this system is consistent with the current United States Comprehensive Soil Classification System.

Data Accumulation and Management

The county level is used as the smallest geographical unit for data gathering. Figure 1 depicts various great group associations in Oklahoma which are shown by letter and number codes. For simplicity of discussion, let Noble County be treated as a region. The soil in this region is of the order Mollisols (M) and the great group code M16. From published data [12], one can determine that in great group code M16, great group Paleustolls dominates (approximately 53 percent) with both Arguistolls (26 percent) and Ustochrepts (21 percent) present. A provisional estimate of cropland in each great group was derived for Noble County as follows:

$$C_g^r = \left(\frac{T_g^r}{\sum_{g=1}^{P} T_g^r} \right) \cdot N^r \qquad (1)$$

where

C_g^r = total cropland of great group g in region r
T_g^r = total land of great group g in region r
N^r = total cropland in region r from most current source (usually census figure)
P = number of great groups in region r.

Assuming N^r=235,483 acres [10], Table 1 indicates the number of cropland acres in each of the three great groups in the Noble County region. Since there is only one great group code defined for Noble County, the above percentages (53%, 26% and 21%) can be applied to total cropland to obtain the estimates in Table 1. However, when more than one code exists, a planimeter is used to estimate total land in each code which is then divided into great groups. Formula (1) is applied to obtain a cropland estimate in each great group.

Applying the four defined capability classes from the previous section, regional cropland acreage in each land class was determined as follows:

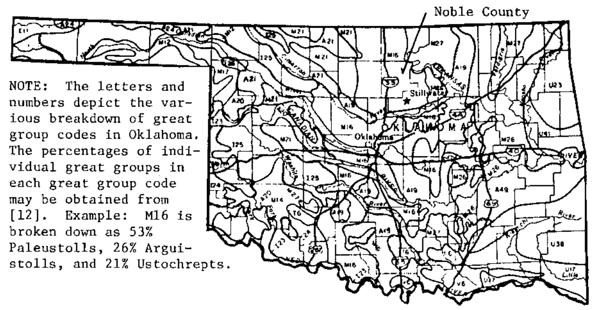

FIGURE 1. SOIL ASSOCIATIONS OF THE GREAT GROUPS OF OKLAHOMA [12]

$$Y_L^r = \left(\frac{M_L^r}{T_L^r} \right) \cdot S_L^r \qquad (2)$$

where

Y_L^r = provisional cropland estimate of land class L in region r
M_L^r = CNI cropland estimate of land class L in region r [6]
T_L^r = CNI total land estimate of land class L in region r [6]
S_L^r = regional soil survey estimate of land class L in region r [14]. (If not available, CNI estimates may be used.)

TABLE 1. ACRES OF CROPLAND BY GREAT GROUPS AND CAPABILITY CLASSES WITH INDICATED KEY SOIL SERIES, NOBLE COUNTY, OKLAHOMA

Great Group	Cropland (acres)	Representative (Key) Soil Series [3]
Paleustolls	124,806	Kirkland*, Norge, Tillman,
Class I	23,064	Bethany, Renfrow
Class II	48,277	
Class III	32,745	
Class IV	20,720	
Argiustolls	61,225	Zaneis*, St. Paul, Richfield,
Class I	11,314	Pondcreek, Kingfisher
Class II	23,683	
Class III	16,064	
Class IV	10,164	
Ustochrepts	49,452	Darnell*, Quinlan, Dill
Class I	9,139	
Class II	19,128	
Class III	12,975	
Class IV	8,210	

*Dominant Soil Series in great group for Noble County.

For example, 56 percent of class I land is in cropland, as well as 94 percent of Class II land, 44 percent of class III land and 62 percent of class IV land. Multiplying these percentages times the respective summation of each class for Noble County [14] yields the provisional estimates of 49,819 acres (class I cropland), 104,278 acres (class II cropland), 70,730 acres (class III cropland) and 44,754 acres (class IV cropland).

To be consistent with latest cropland estimates, the above results were adjusted using the following formulation:

$$X_L^r = Y_L^r\left(\frac{N^r}{\sum_{L=1}^{4} Y_L^r}\right); X_L^r \leq Y_L^r \qquad (3)$$

where

X_L^r = adjusted cropland acreage of land class L in region r

Y_L^r = provisional cropland estimate of land class L in region r

N^r = total cropland in region r from most current estimate.

Adding land classes across great groups (Table 1) yields the adjusted cropland acreage of each land class in Noble County.

An estimate of cropland acreage linking great groups and land classes was determined as follows:

$$X_{gL}^r = \left(\frac{T_g^r}{\sum_{g=1}^{P} T_g^r}\right) \cdot X_L^r = \left(\frac{C_g^r}{N^r}\right) \cdot X_L^r \qquad (4)$$

where

X_{gL}^r = adjusted class L cropland acreage in great group g for region r

T_g^r = total land of great group g in region r

C_g^r = total cropland of great group g in region r

N^r = total cropland in region r from most current source (usually census figure)

X_L^r = adjusted cropland acreage of land class L in region r

As an example, 43,517 acres of adjusted class I cropland was divided among great groups according to their percentage breakdown. (Class I—Paleustolls = 43,517 × 53% = 23,064 etc.)

Table 1 gives a summary of these calculations for the example region Noble County. Also in Table 1, representative soil series of each great group are indicated. With this breakdown, enterprise budgets can be constructed for each great group and each capability class using these key soil series as references for yields and management practices.

When applying CNI percentages of cropland by capability class as above, county soil surveys are desirable, since they provide a complete enumeration of each county's land base. However, because these surveys are not available for some counties, CNI data may be used as a proxy for survey data. CNI data are based on an approximate two percent sample.

Briefly, to review data accumulation procedures, the first step is to accumulate acres of the great groups by county. Four capability classes are then redefined for each great group from eight reported classes with cropland acreage figures accumulated by county and class from the CNI. The percentages in each class are applied to county survey data or, when survey data are not available, CNI cropland estimates are used. These classes are then adjusted by an appropriate ratio in order to conform to the latest cropland figures. Representative soil series are associated with each great group. Enterprise budgets can now be constructed by capability classes within the great group. Larger regions may be defined by accumulation of county data.

A Note on Enterprise Budgeting

This section describes how productivity measures are assigned to selected enterprises. As mentioned earlier, representative or benchmark soil series are the key link between the great group classification and enterprise budgeting. Table 2 depicts yields of three crops for selected benchmark soil series which represent the three great groups in Table 1 [2].

TABLE 2. ESTIMATED YIELDS FOR SELECTED REPRESENTATIVE SOIL SERIES FOR THE GREAT GROUPS OF NOBLE COUNTY

Soil Type	Slope Phase	Cap. Class (CNI Def.)	Wheat bu./ac.	Cotton lbs./ac.	Alfalfa tons/ac.
Norge loam (Paleustolls)	0 - 1	I	30	400	3.0
	1 - 3	II	29	375	2.5
	3 - 5	III	25	300	2.0
	5 - 8	IV	20	NS*	NS
Kingfisher silt loam (Argiustolls)	0 - 1	I	31	315	1.5
	1 - 3	II	29	240	1.0
	3 - 5	III	25	200	NS
Dill fine silt loam (Ustochrepts)	1 - 3	III	19	280	NS
	3 - 5	IV	16	240	NS

*Not suitable.

The relationship between capability class and soil productivity is sometimes confusing. For example, the assignment of successively lower yields to all crops in a region for capability classes I-VIII (CNI definition) without regard to specific soil series is erroneous. If a region has only one great group and a specific soil series is chosen to represent this great group, this assignment would be correct. This is not the case, however, if more than one great group and its representatives are assigned for a region. For example, a class II benchmark soil for one great group may yield more than a class I benchmark soil for another. In Table 2, note the larger alfalfa yield for class II soil in the Norge loam series than for Class I soil of the Kingfisher silt loam series. Also, note that the same capability class for different benchmark series yields different quantities in some instances. Input quantities and management practices used in each budget would be dependent on the productivity as well as the type of chosen representative soil.

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