Taxonomic Structure, Distribution, and Abundance of the Soils in the USA

Yinyan Guo, Ronald Amundson,* Peng Gong, and Robert Ahrens

ABSTRACT

In this paper, we report the taxonomic structure, the spatial distribution, and relative abundance of soils in the USA. In the analysis, we used the STATSGO (1997 version) database, which contains information on 11 orders, 52 suborders, 232 great groups, 1175 subgroups, 6226 families, and 13 129 series. The analysis of taxonomic structure showed that the numbers of taxa in any category were distributed unevenly in relation to taxa present at the next higher category. This uneven distribution becomes more pronounced in the lower categories of the hierarchy. In addition, there is a trend for taxa to produce only one, or a very small number, of taxa in the next lower category at the lower categories of the system. The analysis of the spatial distribution of taxa showed that 10 662 (51.2%) out of 20 825 taxa exist only 1 Major Land Resource Area (MLRA), indicating that most soil taxa are not widely spread, and are specific to particular combinations of state factors. The area abundance of soil taxa is asymmetric with most taxa in a category having relative small area extent. Five (2.1%) great-groups, 37 (2.1%) subgroups, 417 (6.7) families, and 827 (6.3%) series had total areas less than 10 km^2, and were defined as rare taxa. Among the rare taxa, four (80%) rare great groups, 36 (97.3%) rare subgroups, 378 (90.6%) rare families, and 750 (90.7%) rare series were found in only 1 MLRA. The portion of rare soils might be much higher because not all the soils are included in STATSGO because of their too limited area. The spatial and area abundance analyses of the soils provides a perspective useful for discussions on the preservation of soil resources in the USA, a topic whose importance is likely to grow in conjunction with increasing interest in global biodiversity and more intense uses of the world's soil resources.

In early 1899, the USA launched The National Cooperative Soil Survey Program to inventory soils at a national scale (Smith, 1983; Morse, 1999). The methods for classifying soils were gradually improved as more soil surveys were conducted. The primary soil unit or taxon in field mapping was the soil series, or phase of series. Over the past century, as the concept of series has evolved, the number of series identified in the USA has grown to more than 21 000 (http://soils.usda.gov; verified 13 May 2003). The result of several attempts to generate a system to place systematically all these soils within an integrated organizational framework resulted in the present USDA/NRCS Soil Taxonomy (Marbut, 1922, 1935; Baldin et al., 1938; Albeiter, 1949; Smith, 1963, 1983, 1984; Soil Survey Staff, 1960, 1975, 1987, 1990, 1994, 1996, 1998). The current Soil Taxonomy (Soil Survey Staff, 1999) includes six taxonomic categories (in decreasing rank): order, suborder, great group, subgroup, family, and series. Today, U.S. Soil Taxonomy is the most widely used system of soil classification worldwide (Yaalon, 1995, 1996; Malcolm et al., 2000, p. E117–135).

Despite the wide acceptance of the system as a means of organizing soil information, there has been no systematic analysis on the distribution of U.S. soils within the system and with space, nor has there been a systematical analysis of the area abundance of the taxa lower than the suborder category. Taxa are unevenly distributed, and some are rare, because the factors required for their development are not extensive in the USA. A better understanding of these characteristics may become increasingly important as the intensity of land use increases and questions arise on the resulting effect on soil resources. The purpose of this paper is to examine the taxonomic structure, spatial distribution, and relative abundance of the taxa in the USA by means of the State Soil Geographic database (STATSGO) (SCS, 1992; Reybold and Gale, 1989). The analysis provides results useful to determine how the present taxonomy succeeds in separating soils and provides information potentially useful to soil preservation and conservation planning.

Y. Guo, R. Amundson, and P. Gong, Division of Ecosystem Sciences and Center for Assessment and Monitoring of Forest and Environmental Resources (CAMFER), 151 Hilgard Hall, College of Natural Resources, University of California, Berkeley, CA 94720-3110; R. Ahrens, National Soil Survey Center, USDA-NRCS-NSSC, Federal Building, Room 152, MS32, 100 Centennial Mall north, Lincoln, NE 68508-3866. Received 14 March 2002. *Corresponding author (earthy@nature.berkeley.edu).

Published in Soil Sci. Soc. Am. J. 67:1507–1516 (2003).

MATERIALS AND METHODS

Data Sources

The 1997 version of STATSGO was the database used in this study (SCS, 1992; Reybold and Gale, 1989). STATSGO is a Geographic Information System (GIS) based relational database compiled by the National Resources Conservation Service (NRCS), which was made by generalizing detailed soil survey data. The level of mapping detailed in STATSGO was designed for broad planning and management uses covering state, multi-state, and regional areas, and is the only soil database available for evaluating abundance and distribution of national soil resources. The mapping scale for the STATSGO data is 1:250 000 (with the exception of Alaska, which is 1:1 000 000) with a minimum mapping unit area of 6.25 km^2. Some soil series are not included in the STATSGO database if their area is too limited to fit this scale. Data for all 50 states and the Puerto Rico territory were used. The original projection of STATSGO was retained except that the datum was changed from Clarke 1866 to NAD83 by ARC/INFO software (Environmental Systems Research Institute, 1998).

Method of Analysis

The basic structure of STATSGO consists of the map unit and its components. Soil components are the associated phases of soil series. A map unit may contain 1 to 21 soil components. Within the 10 796 map units (76 845 polygons) in STATSGO there are 113 465 soil components that have recorded soil taxonomic information. For each soil component, the percent-

Table 1. Number of the taxa within each soil order recorded in STATSGO.

Order	Suborder	Great group	Subgroup	Family	Series
Alfiosols	5	31	189	930	2 250
Andisols	6	15	41	118	204
Aridisols	2	11	99	691	1 627
Entisols	5	27	126	993	1 718
Histosols	4	15	50	90	144
Inceptisols	5	32	184	909	1 556
Mollisols	7	32	261	1 853	4 285
Oxisols	4	12	19	20	28
Spodosols	4	19	75	187	349
Ultisols	5	21	84	323	745
Vertisols	5	17	47	112	223
Sum	52	232	1 175	6 226	13 129

age of the component occupied in the map unit as well as taxonomic information for the six taxonomic categories of the Soil Taxonomy (Soil Survey Staff, 1975, 1999) are reported. The number of the taxa recorded in STATSGO is presented in Table 1. The area of a taxon in each map unit was calculated by multiplying the component percentage by the area of the map unit (which consists of the area of several GIS polygons). The total area of each taxon was summarized from all 51 states or territory. The areas of all taxa in each taxonomic category were calculated.

The tree of the soil taxa, i.e., the number of taxa in a lower category generated by the taxon in the next higher category, was developed for all categorical levels.

Major Land Resource Areas (MLRAs) are geographically associated land resource units that are characterized by a restricted pattern of soils, climate, water resources, and land uses (Soil Survey Staff, 1981). MLRAs are designated numerically and identified by a descriptive geographic name (Fig. 1). When preexisting MLRAs are revised, an alphabetic suffix is added to the original number. In this study, different alphabetic suffixes with the same number were considered as the same MLRA. Each map unit has MLRA information stored in STATSGO. The spatial width of the taxa (the number of MLRAs in which each taxon existed) was analyzed.

Histograms of taxa abundance were based on the number of taxa in each category. If the number was <50, the taxa were grouped into 10 classes. If the number was ≥ 50 and <250, the taxa were grouped into 25 classes. If the number was ≥ 250, the taxa were grouped into 50 classes. Frequency histograms on the abundance of taxa below the suborder category were made with equal intervals in each class based on the area abundance of the taxa.

All computations were processed by means of programs compiled by the authors with Visual Basic in Microsoft Access (Microsoft Corporation, 2000) and Avenue in ArcView GIS (Environmental Systems Research Institute, 1999).

RESULTS AND DISCUSSION

Taxonomic Structure of the Soils in the USA

There are six categories of taxonomic tree "branches" in the current soil taxonomic system, though the structure of the tree, and the number of "leaves," provides an interesting perspective into the way the Soil Taxonomy works. To understand this structure, the number of suborders generated by each order is presented in Table 1 and the number of taxa generated by the remaining categories is summarized in Fig. 2. To explain these results in detail, Alfisols are used as an example. Alfisols contain five suborders. Among these suborders (graph segment A), two suborders each contain six great groups (2×6) while the other three contain four (1×4), 7 (1×7), and eight (1×8) great groups, respectively. The 31 great groups were further divided into 189 subgroups (graph segment B). Two of the 31 great groups contain only one subgroup (2×1) while another seven contain only two subgroups (7×2). The remaining great groups each have 3 to 18 subgroups. The subgroups were divided into 930 families (graph segment C): 46 of the 189 subgroups contain only one family while the rest contain 2 to 28 families. The single-family subgroups constitute 24.3% of the total subgroups. The 930 families were divided into 2250 series (graph segment D), with 515 (55.4%) containing only one series (Fig. 2, Table 1).

A general pattern of the soil taxonomic structure is the uneven numbers of the subcategory taxa. For example, the number of suborders contained in each of the 11 orders varies from two to seven and the great groups in each of the 52 suborders varies from 1 to 10. This trend of unevenness increases as the hierarchical category decreases. Each of the 232 great groups contains 1 to 26 subgroups, the 1175 subgroups contain 1 to 65 families, and the 6226 families contain 1 to 43 series. The percentage of the taxa that contain only one subtaxon increases dramatically in the lower taxonomic categories. While all orders contain more than 1 suborder, 9.6% (5) of suborders, 15.9% of (37) great groups, 25.2% (296) of subgroups, and 55.8% (3477) of families contain only one taxon in their next lower category. This phenomenon likely occurs because of the practical need to develop a new lower category for unusual soils as they are encountered.

Specific patterns of the taxonomic structure and distribution vary from one soil order to another. For example, Oxisols contain a small set of taxa, while Mollisols, Entisols, and Alfisols each contain a large set of taxa. The largest number of taxa contained in each categorical level are Mollisols with seven suborders; Aquepts with 10 great groups; Haploxerolls with 26 subgroups; and Typic Haplaquolls with 65 families. At the family level, fine-loamy, mixed, mesic Typic Hapludalfs contain 43 series. In contrast, eight (66.7%) great groups, 18 (94.7%) subgroups, and 15 (75.0%) families contain only one taxon at the next lower category in the Oxisol order.

The differences among the taxonomic structure of the orders (or any category) likely reflects a combination of real differences in the range of soil and environmental characteristics of these groups and the degree to which each order has been developed during the evolution of the taxonomy. However, some attributes of the data set may also contribute to the patterns. In STATSGO, taxonomic information of taxa in the lower categories is not complete. For example, soil components in Alaska are only reported to the subgroup category, and this missing taxonomic information in the lower categories has not considered or addressed in this study. Second, not all soils are included in STATSGO because of the current STATSGO scale. Finally, revisions in soil taxon-

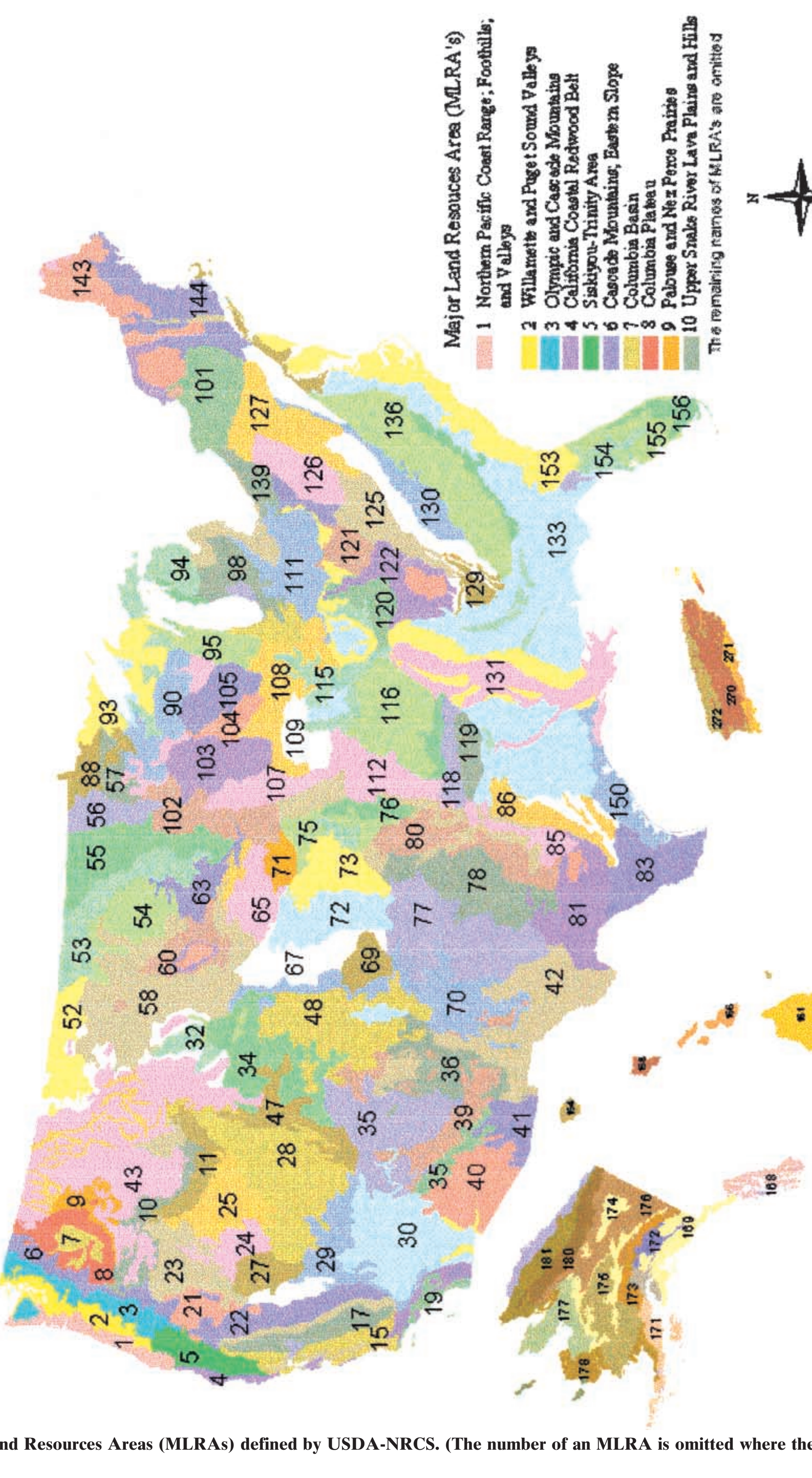

Fig. 1. Major Land Resources Areas (MLRAs) defined by USDA-NRCS. (The number of an MLRA is omitted where the area is too small to fit a number).

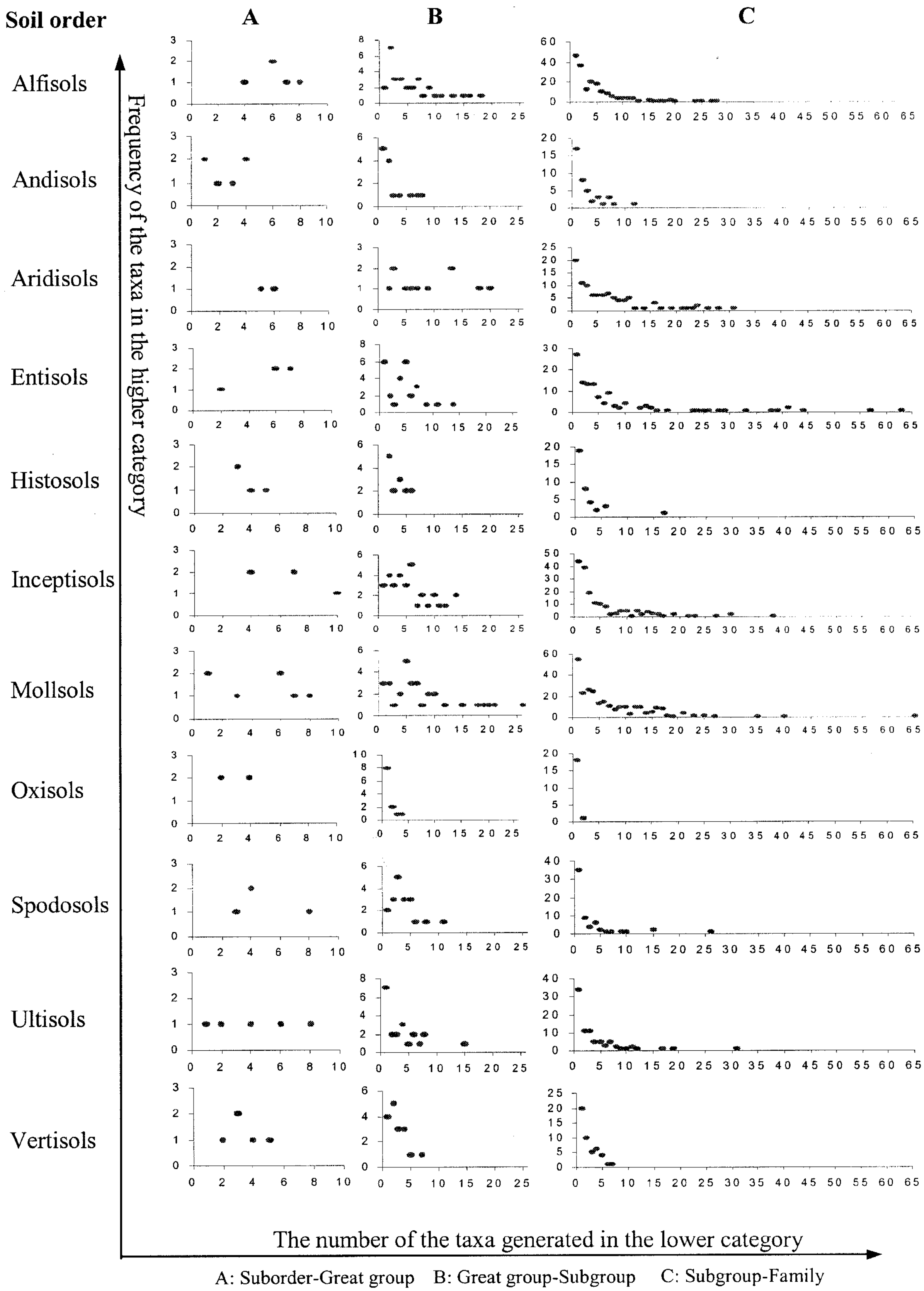

Fig. 2. Continued

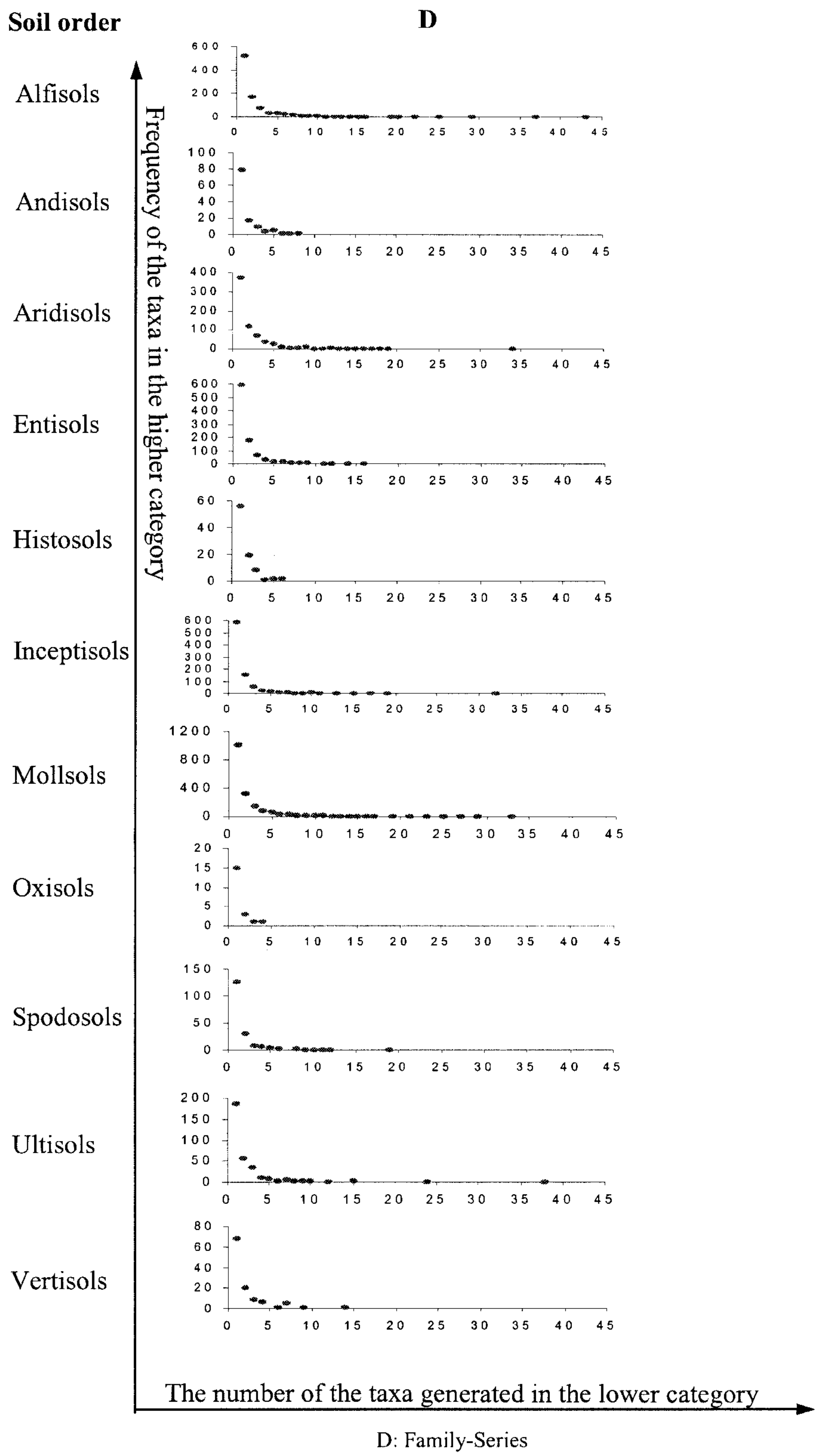

Fig. 2. The taxonomic structure of the taxa in each category of the Soil Taxonomy.

omy since the 1997 STATSGO version was compiled have changed taxa throughout the system, a revision that will likely continue as soil taxonomy is further tested and refined to adequately meet observed properties in the field (Soil Survey Staff, 1998; Swanson, 1999). Therefore, while our analysis is based on the 1997 version of STATSGO (with its obvious limitations), our method can be applied to subsequent versions to evaluate how those changes have succeeded in altering the taxonomic structure.

Distribution of the Soils in the USA

The distribution of each taxon in different MLRAs is summarized in Table 2. Alfisols are again used to explain the results of the analysis. Alfisols are found in 139 MLRAs. Considering its five suborders, two exist in 43 MLRAs, while the other three occur in 27, 73, and 81 MLRAs, respectively. Among the 31 great groups, three great groups exist in two MLRAs, four in three to five MLRAs, and the rest occur in 6 to 70 MLRAs. For the 189 subgroups, 26 (13.7%) occur in only one MLRA while the rest exist in 2 to 48 MLRAs. For the 930 families, 402 (43.2%) occur in one MLRA while the rest exist in 2 to 29 MLRAs. For the 2250 series, 1303 (57.9%) occur in one MLRA while the remainders exist in 2 to 11 MLRAs.

A general pattern of spatial distribution (wideness) is that the taxa at the lower categories of Soil Taxonomy become more site specific. As the hierarchical category decreases, the number of MLRAs containing a particu-

Table 2. The distribution of taxa among Major Land Resources Areas (MLRAs).

Orders (Number of MLRAs)	Categories	The number of MLRAs where each taxon exists													
		1	2	3–5	6–10	11–15	16–20	21–30	31–40	41–50	51–60	61–80	81–100	101–120	121–150
Alfisols (139)	Suborders							1		2		1	1		
	Great groups		3	4	5	4	3	6	4			2			
	Subgroups	26	26	49	41	26	9	7	3	2					
	Families	402	205	215	86	15	4	3							
	Series	1303	573	332	41	1									
Andisols (19)	Suborders		1	1	2	2									
	Great groups	3	4	4	3	1									
	Subgroups	17	11	10	3										
	Families	75	29	14											
	Series	168	30	6											
Aridisols (58)	Suborders										2				
	Great groups				1	3	2	1	2	1	1				
	Subgroups	16	9	19	32	14	7	2							
	Families	315	143	171	54	7	1								
	Series	1057	360	197	13										
Entisols (171)	Suborders				1										4
	Great groups	2		5		2	3	4	2	4	2	2		1	
	Subgroups	16	11	34	20	14	8	14	4	3		2			
	Families	404	234	221	110	16	7	1							
	Series	886	429	332	68	3									
Histosols (80)	Suborders				1			1	1		1				
	Great groups		2	5	2	2	1	2		1					
	Subgroups	12	14	11	5	4	2		2						
	Families	28	22	25	9	3	3								
	Series	73	29	27	12	3									
Inceptisols (157)	Suborders					1		1		1				1	1
	Great groups	1	3	6	7	5		5	1	1	2	1			
	Subgroups	43	35	38	30	17	10	7	3	1					
	Families	454	186	211	49	6	2	1							
	Series	981	330	225	15	4	1								
Mollisols (151)	Suborders						1		2		2	1			1
	Great groups	1	1	1	5	3	3	5	7	1	3	1		1	
	Subgroups	32	23	59	52	38	28	18	7		3	1			
	Families	773	376	429	208	54	13								
	Series	2457	998	743	86	1									
Oxisols (5)	Suborders		2	2											
	Great groups	6	5	1											
	Subgroups	15	3	1											
	Families	16	4												
	Series	24	4												
Spodosols (51)	Suborders			1				1	2						
	Great groups	3	1	3	7	2	2	1							
	Subgroups	22	18	15	15	5									
	Families	89	52	37	9										
	Series	185	107	56	1										
Ultisols (61)	Suborders				2	1			1	1					
	Great groups	3	1	1	9	3	1	2		1					
	Subgroups	18	10	24	22	4	3	2	1						
	Families	132	81	71	28	9	1	1							
	Series	413	177	131	23	1									
Vertisols (70)	Suborders				1	1	2		1						
	Great groups	2	3	4	1	4	2	1							
	Subgroups	10	10	12	10	5									
	Families	49	30	27	6										
	Series	130	54	38	1										

lar taxon decreases and the percentage of taxa falling within only one MLRA increases. While a particular order can be found in 5 to 171 MLRAs, a suborder may occur in 2 to 146 MLRAs; a great group in 1 to 112 MLRAs; a subgroup in 1 to 78 MLRAs; a family in 1 to 29 MLRAs, and a series in 1 to 16 MLRAs. From a percentage perspective, 9.1% (21) great groups, 19.3% (227) subgroups, 44.0% (2737) families, and 58.5% (7677) series are found in only one MLRA. The result illustrates the environmental characteristics that define the unique MLRAs also constitute significant controls on pedological development and distribution. Specific patterns of wideness vary among the soil orders. Entisols are the most widely spread taxon: 171 of 172 MLRAs have Entisols (the exception being MLRA141, Tughill Plateau in New York). In contrast, Oxisols exists in only five MLRAs. The most widely spread suborder are the Fluvents, existing in 146 MLRAs while, in contrast, three suborders (Humox, Orthox, and Torrands) occur in only two MLRAs. Haplaquolls (112 MLRAs) and Typic Fluvaquents (78 MLRAs) are the most widely spread great group and subgroup. The most widely spread family are the mixed, mesic Typic Udipsamments and fine-loamy, mixed mesic Typic Haludalfs, both existing in 29 MLRAs. The most widely spread soils series is the Berks series (loamy-skeletal, mixed active, mesic Typic Dystudepts), which occurs in 16 MLRAs. In contrast, for Oxisols, 50.0% (6) of its great groups, 78.9% (15) of its subgroups, 80.0% (16) of its families, and 85.7% (24) of its series exist in only one MLRA. For Andisols, 63.6% (75) of families, and 82.4% (168) of series exist in 1 MLRA. Entisols are the most widely spread taxa because the most regions of the country contain geologically young landforms. Vertisols, Andisols, and other selected orders and lower categories occur in the regions with specific geological conditions that partially define the MLRA.

The distribution of soils among the MLRAs is understandable in terms of soil formation. The constellation of state factor values that control soil development varies continuously and greatly with space (Jenny, 1941), which will be reflected in the spatial distribution of soils at all categories of the classification, especially at family and series categories. As recorded in STATSGO, 10 662 (51.2%) out of 20 825 taxa in all the taxonomic categories fall into only one MLRA. The numbers of taxa that occur only in one MLRA might be expected to be much higher if all soils in USA were included in STATSGO, since those excluded have very small area extents and are likely to be more restricted to specific locations and associated state factors. This trend toward "soil endemism," particularly at the series level, has important implications regarding the preservation of natural soil diversity in the face of land use activity (Amundson, 1998, 2000; Ibáñez et al., 1995). The preservation of undisturbed tracts of specific soil characteristics that are highly restricted geographically is difficult to achieve in the face of highly concentrated land activities such as agriculture. Although these concepts are intuitively recognized by pedologists, our analysis provided a quantitative measure of the soil "endemism" in the USA.

Abundance of the Soils in the USA

The area and distribution of the 12 orders and 64 suborders established in the current taxonomic system have been recently published on the basis of STATSGO (Soil Survey Staff, 1999). However, there is no information available about the abundance of the taxa lower than the suborder category. Here we present the abundance distribution of the taxa below the suborder category using STATSGO (1997 version) (Fig. 3, Table 3). Discussion again focuses on Alfisols as an example. The 31 great groups of Alfisols were grouped into 10 classes with an interval of 40 741 [(407 468 − 56)/10] km^2: 22 (71.0%) of great groups fall into class 1 with a range of 56 to 40 797 km^2 while the other nine fall into class 2, class 3, and class 10, in which have six, two, and one great groups, respectively. The 189 subgroups were grouped into 25 classes with an interval of 8342 [(208 549 − 4)/25] km^2: 155 (82.0%) subgroups are in class 1 with a range of 4 to 8346 km^2, while the other 34 are in class 2, class 3, class 4, class 5, class 6, class 7, class 9, and class 25 with 17, 7, 2, 4, 1, 1, 1, and 1 subgroups, respectively. The 930 families were grouped into 50 classes with an interval of 1041 [(52 067 − 0.14)/50] km^2: 689 (74.1%) families are in class 1 with a range of 0.14 to 1041 km^2, while the rest are in class 2 through class 50, respectively. The 2250 series were grouped into 50 classes with an interval of 342 [(17 115 − 0.14)/50] km^2: 1467 series (65.2%) are in class 1 with a range of 0.14 to 342 km^2, while the rest are in classes 2 through class 50, respectively. The abundance distributions of the other orders have the same pattern as that of Alfisols (Fig. 3), thus only the range of the abundance (minimum and maximum abundance) in each categorical level of the remaining nine orders is presented in Table 3.

The general pattern of the abundance distribution of the taxa is that the distributions are asymmetric, i.e., all of the abundance distributions are positively skewed, concentrated around the left end, and close to the taxon with the smallest abundance. This distinctive feature is a typical lognormal distribution (Crow and Shimizu, 1988), which indicates that most of the U.S. soils are relative small in area extent. It is important to note that the shape of the histogram is influenced, to a certain degree, by the number of classes chosen. Figure 3 was made so that as few classes as possible were chosen given the number of the taxa at each category.

The abundance varies dramatically among the taxa at each taxonomic category. The largest great group, subgroup, family, and series are Cryaquepts (571 322 km^2), Histic Pergelic Cryaquepts (405 722 km^2), clayey, kaolinitic, thermic Typic Kanhapludults (91 303 km^2), and the Valentine series (mixed, mesic Typic Ustipsamments) (43 735 km^2), respectively. The Valentine series is the dominant soil in the sandhills of Nebraska, one of the largest dune fields in the world. Cryaquepts are abundant because they are partially defined by cold temperatures that occur over a large land area in Alaska. If only the soils in the conterminous USA are considered, the largest great group, subgroup, family, and series are Hapludalfs (407 213 km^2), Typic Hapludults

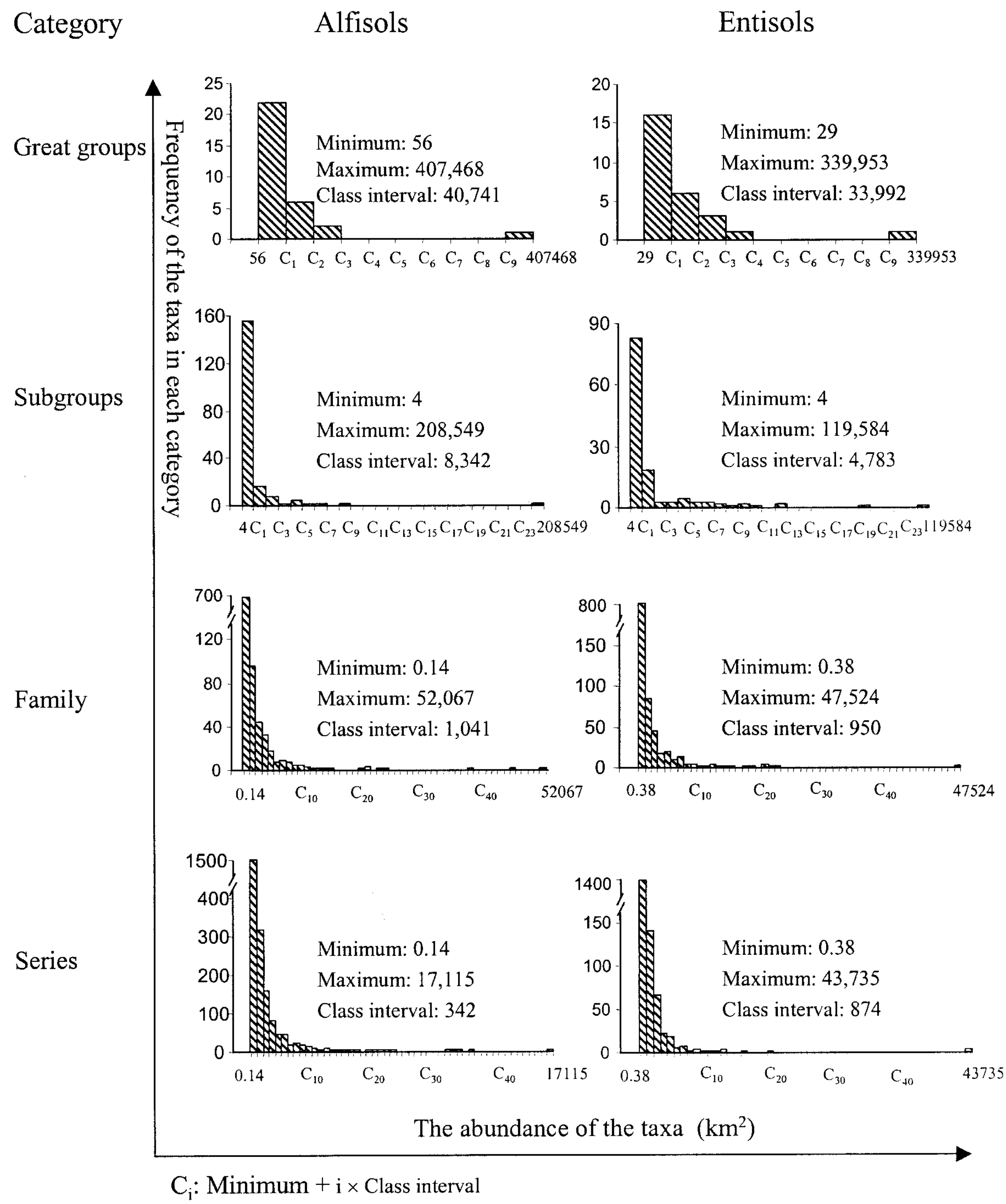

Fig. 3. The abundance distribution of the taxa in four categorical levels of Alfisols and Entisols.

(255 133 km^2), clayey, kaolinitic, thermic Typic Kanhapludults (91 303 km^2), and the Valentine series (mixed, mesic Typic Ustipsamment) (43 735 km^2), respectively. If taxa less than 10 km^2 in area extent are defined as rare soils, then five (2.1%) great groups fit this category, including Tropohumods (0.31 km^2), Acrorthox (2.4 km^2), Eutrudox (2.41 km^2), Plinthaquults (6.39 km^2), and Tropohemists (6.78 km^2). At the subgroup category, 37 (3.2%) subgroups are rare, with Typic Tropohumods (0.31 km^2) and Grossarenic Entic Haplohumods (0.62 km^2) being the smallest subgroups. There are 417 (6.7%) families less than 10 km^2 in area, in which 203 (48.7%) are less than 5 km^2, and 21 (5.0%) are less than 1 km^2. At the series category, 827 (6.3%) series are less than 10 km^2 in area, in which 345 (41.7%) are less than 5 km^2 and 35 (4.2%) are less than 1 km^2. Some of the rare soils discussed above are associated with tropical climates and stable land masses that are more common in tropical than temperate regions, and the USA has a limited area of these tropical regions. These rare taxa were further analyzed with respect to the spatial distribution among the MLRAs: 4 (80%) of the rare great

Table 3. The range of taxa abundance (km^2) in four categories of the remaining nine soil orders.

	Great group		Subgroup		Family		Series	
Orders	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Andisols	11.00	42 590	11.00	34 800	4.00	6 653	3.00	6 481
Aridisols	4 133.00	290 548	6.00	107 248	0.80	37 305	0.56	10 371
Histosols	7.00	100 048	2.00	89 229	2.00	12 003	2.00	8 711
Inceptisols	39.00	571 322	2.00	405 722	0.26	62 876	0.26	19 419
Mollisols	174.00	270 827	1.00	87 013	0.44	44 864	0.21	26 709
Oxisols	2.00	711	2.00	445	2.00	435	2.00	435
Spodosols	0.31	160 386	0.31	76 006	0.08	40 537	0.08	9 954
Ultisols	6.00	325 778	4.00	255 289	0.94	91 303	0.94	37 121
Vertisols	17.00	29 797	11.00	15 253	0.70	11 271	1.00	6 546

groups, 36 (97.3%) of the subgroups, 378 (90.6%) of the families, and 750 (90.7%) of the series exist in only one MLRA. Because a large number of series are excluded from the STATSGO database because of their limited area extent, there are other more rare taxa that exist in the USA, but do not show up in our analysis. To capture fully the number and location of all rare soils will require the use of the Soil Survey Geographic database (SSURGO), which presently only is available for select locations in the USA (Reybold and Gale, 1989). Regardless, our analysis illustrates that a large number of soils in the USA are rare. Rare soil may have its own unique ecological function or historical information. It will be useful to evaluate the value of their qualities in future work.

The USA represents a relatively small area of the world. Therefore, it may be argued that soils described above may not be rare if the entire earth is considered. The data to test this hypothesis are currently not available. However, according to our work, it would seem that soils are not widely spread and that they appear to be specific to particular locations. Therefore, it is possible that many rare soils defined in our study might also be rare when viewed in a global context.

Soils are nonrenewable natural resources with a variety of economic, aesthetic, scientific, and ecological value (Amundson et al., in press). The intense, localized conversion of many sections of the USA to agriculture and urban uses is threatening the fate of soils that are distributed uniquely in those locations. Our results on the rare (<10 km^2 in extent) and unique (existing only in one MLRAs) taxa provide data useful for discussions of soil resource conservation and preservation and land use planning.

SUMMARY AND CONCLUSIONS

We conducted the first exploration of the taxonomic structure, spatial wideness, and abundance distribution of the soils in the USA on the basis of the STATSGO soil database (1997 version). A general pattern of the taxonomic structure is that an uneven number of the taxa exist in a given category. This uneven distribution becomes more pronounced in the lower categorical levels of the hierarchy. Additionally, the spatial distribution of taxa showed that 10 662 (51.2%) out of 20 825 taxa studied, especially those taxa in the lower categorical levels, exist in only one MLRA and are therefore specific to particular locations and associated state factors. The abundance distribution of soils is asymmetric, concentrated close to the taxon with the smallest abundance, suggesting that the area extent of most soils is very limited. Five (2.1%) great groups, 37 (2.1%) subgroups, 417 (6.7) families, and 827 (6.3%) series were less than 10 km^2 in area (rare taxa as defined in this study). Among the rare taxa, four (80%) rare great groups, 36 (97.3%) rare subgroups, 378 (90.6%) rare families, and 750 (90.7%) rare series were found in only one MLRA. The portion of rare soils might be much higher because not all the soils are included in STATSGO because of their too limited area. Results of this study provide an overview on the taxonomic structure of the soils in the USA. The spatial and abundance analyses of the soils provide a perspective useful for discussions of the rarity and preservation of soil resources in the USA, a topic whose importance is likely to grow in conjunction with increasing interest in global biodiversity and greater and more intense human uses of the world's soil resources.

ACKNOWLEDGMENTS

We thank Kit Paris, Eric Vinson, Sharon Waltman, and Norman B. Bliss for detailed explanations of the STATSGO database; Doug Miller and Sharon Waltman for providing MLRA coverage; Jin Chen and Lan Mu for GIS technical assistance and Ming Xu for commenting an earlier draft of this paper. This research was partially supported by the Kearney Foundation of Soil Science.

REFERENCES

Albeiter, J.K. 1949. Soil classification in the United States. Soil Sci. 67:183–191.

Amundson, R. 1998. Do soils need our protection? Geotimes March:16–20.

Amundson, R. 2000. Are soils endangered? p. 144–53. *In* J. Schneiderman (ed.) The earth around us, maintaining a livable planet. WH Freeman and Co., New York.

Amundson, R., Y. Guo, and P. Gong. Soil diversity and land use in the United States. Ecosystems (in press).

Baldin, M., C.E. Kellogg, and J. Thorp. 1938. Soil classification. p. 979–1001. *In* Soils and men. U.S. Dep. Agric. Yearbook. U.S. Gov. Print. Office, Washington, DC.

Crow, E.K., and K. Shimizu. 1988. Lognormal distributions: Theory and applications. M. Dekker, New York.

Environmental Systems Research Institute. 1999. Arcview GIS 3.2 software. http://www.esri.com/software/arcview/; verified 6 May 2003.

Environmental Systems Research Institute. 1998. Arc/info 7.2.1 (unix) software. http://www.esri.com/software/arcgis/arcinfo/; verified 6 May 2003.

Ibáñez J.J., S. De-Alba, F. F. Bermúdez, and A. García-Álvarez. 1995. Pedodiversity: Concepts and measures. Catena 24:215–32.

Jenny, H. 1941. Factors of soil formation. A system of quantitative pedology. 1st ed. McGraw-Hill Book Co., New York.

Malcolm, E.S., et al. 2000. Handbook of soil science. CRC Press, Boca Raton, FL.

Marbut, C.F. 1922. Soil classification. Am. Soil Survey Assoc. Bull. 3:24–32.

Marbut, C.F. 1935. Soils of the United States, Part III. p. 1–98. *In* Atlas of American agriculture. U.S. Dep. Agric., U.S. Gov. Print. Office, Washington, DC.

Microsoft Corporation. 2000. Microsoft Access software. http://www.microsoft.com/office/access/; verified 6 May 2003.

Morse, D. 1999. 100 years old (The centenary of the U.S. National Cooperative Soil Survey program). Resource: Engineering and technology for a sustainable world 6:11–12.

Reybold, W.U., and W.T. Gale. 1989. Soil geographic data bases. J. Soil Water Conserv. 44(1):28–30.

SCS. 1992. State soil geographic data base (STATSGO) data user guide. USDA-SCS. National Soil Survey Center, Lincoln, NE. Available also online: http://www.ftw.nrcs.usda.gov/stat_data.html; verified 6 May 2003.

Smith, G.D. 1963. Objectives and basic assumptions of the new classification system. Soil Sci. 96:6–16.

Smith, G.D. 1983. Historical development of soil taxonomy-background. p. 23–49. *In* L.P. Wilding et al. (ed.) Pedogenesis and soil taxonomy I. Concepts and interaction. Elserier, New York.

Smith, G.D. 1984. Guy D. Smith discusses soil taxonomy. SSSA, Madison, WI.

Soil Survey Staff. 1960. Soil classification, a comprehensive system, 7th approximation. Soil Conservation Service, U.S. Dep. Agric., U.S. Gov. Print. Office, Washington DC.

Soil Survey Staff. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. U.S. Dep. Agric. Handbook 436. U.S. Gov. Print. Office, Washington DC.

Soil Survey Staff. 1981. Land Resource Regions and Major Land Resource Areas of the United States. USDA Agriculture Handbook 296. USDA Natural Resources Conservation Service (formerly Soil Conservation Service), National Soil Survey Center, Lincoln, NE. Available also online: http://www.statlab.iastate.edu/soils/MLRAweb/mlra/; verified 6 May 2003.

Soil Survey Staff. 1987. Keys to soil taxonomy. 3rd print. Dep. of Agronomy, Cornell University, Agency for International Development, U.S. Dep. of Agriculture, Soil Management Support Services, Ithaca, NY.

Soil Survey Staff. 1990. Keys to soil taxonomy, 4th ed. Agency for International Development, United States Department of Agriculture, Soil Management Support Services, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Soil Survey Staff. 1994. Keys to soil taxonomy, 6th ed. U.S. Department of Agriculture, Pocahontas Press, Blacksburg, VA.

Soil Survey Staff. 1996. Keys to soil taxonomy, 7th ed. U.S. Gov. Print. Office, Washington, DC.

Soil Survey Staff. 1998. Keys to soil taxonomy, 8th ed. U.S. Gov. Print. Office, Washington, DC.

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. Second ed. U.S. Dep. Agric. Handbook 436. U.S. Gov. Print. Office, Washington DC.

Swanson, D.K. 1999. Remaking soil taxonomy. Soil Survey Horiz. 40:81–88.

Yaalon, D.H. 1995. The soils we classify-essay review of recent publication on soil taxonomy. Catena 24:233–241.

Yaalon, D. H. 1996. Soil classification. Nature 380(6569):31–32.