Comput., Environ. and Urban Systems, Vol. 16, pp. 389–401, 1992
Printed in the USA.
0198-9715/92 $5.00 + .00

RESOLUTION TOLERANCE IN AN AUTOMATED FOREST LAND EVALUATION MODEL

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ABSTRACT. *The United States Department of Agriculture Soil Conservation Service (SCS) Land Evaluation and Site Assessment (LESA) model was developed in direct response to the National Farmland Protection Policy Act as a consequence of ever increasing demands on the land for nonagricultural uses. LESA's land evaluation (LE) subsystem is a portion of the model designed to determine physical quality of the land for agricultural uses. Previous research has shown that parts of the LESA model can be implemented in automated geographic information systems (GIS). However, no implementation of the forest LE subsystem has been implemented on a GIS, therefore requiring evaluation of land for forestry to be performed manually, one land parcel at a time. Nor have any studies indicated the necessary cell resolution for later incorporation of the LE subsystem within the LESA model. This paper describes a prototype implementation of the forest LE subsystem within a microcomputer based GIS at four separate resolutions. The objective of this project was to test its adaptability to GIS implementation and to ascertain its sensitivity to resolution changes. Results show that the forest LE subsystem is readily adaptable both to GIS implementation and final merger with the site assessment (SA) portion of the LESA model. The model showed little change in outcome as a result of resolution change. Categorical simplification of the modeling process and the broad class values utilized produces this lack of resolution sensitivity, demonstrating that resolution can be selected based on the needs of the SA subsystem.*

INTRODUCTION

In 1981 the Congress of the United States enacted Public Law 97-98, also known as the Farmland Protection Policy Act, in response to increasing demands on the land resource base for activities not directly producing food or fiber (U.S. Congress, 1981). The Department of Agriculture's Soil Conservation Service (SCS) was charged with the responsibility of implementation of the Act (Wright, 1981). The result was the development of a set of evaluative procedures called agricultural land evaluation and site assessment (LESA) (Steiner, 1987).

LESA is made of two subsystems, (a) land evaluation (LE) and (b) site assessment (SA). The LE subsystem is used to rate the physical quality of soils for agricultural, forest or rangeland uses and to rank them from best to worst for the selected study region. Highest quality

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soils are assigned a value of 100 with the remainder of the soils groups given correspondingly lower values. These values are based on data from the National Cooperative Soil Survey (Wright, Zitzmann, Young, & Googins, 1983). A working example of the LESA model as applied to agricultural uses is found in DeMers (1989).

The SA subsystem rates those factors other than soils which contribute to the viability of a site for crop production. These socio-economic factors reflect local land use planning needs and objectives and are compiled by local planners in consultation with local SCS officials. The factors selected for SA could have a maximum total value of 200 points, which, when added to the LE values, provide a 300 point maximum score upon which decisions may be made as to retention or conversion of existing cropland (Wright et al., 1983).

The original design of LESA relegated the data manipulation tasks to manual calculation on an as-needed basis for any given land parcel. Williams (1985) showed that the LESA model could be automated within a raster-based geographic information system (GIS), thus enhancing the model's utility by allowing rapid evaluation of large spatial areas. He established procedures for automating LE for agricultural lands and for merging these results with the SA subsystem of LESA. This was apparently the first such application of formal GIS technology to the LESA model. However, the LE subsystem for forestry that had been established for the LESA model has never been automated, nor have any prototype GIS implementations been attempted.

The forest lands LE subsystem procedures are strikingly different from those used for agricultural lands both in the data types used and the methods of combining them, yet the techniques necessary to automate it within a GIS are readily identifiable. Beyond the mere implementation of the forest LE procedures, however, a fundamental question remains concerning minimum cell size needed for model implementation. Based on sampling theory, the larger the cell size, the more infrequently occurring categories will disappear. This depends on many factors, among them the shapes of the mapped categories, their overall frequencies, and range of resolutions evaluated (Muehrcke, 1986). The major hypothesis in this study is that this GIS prototype will show that the larger the cell size, the more infrequently occurring LE categories will disappear, thus impacting on the model results, especially at the coarsest resolution. It is expected that a given resolution will begin to show the impact of such a loss, thus exposing possible threshold cell size values for GIS implementation of LE within the study region.

To examine this, the prototype uses a grid cell format in which each cell is assigned to a single category based on the highest percentage of a given value within each cell. Selection of the appropriate grid cell size for model implementation is a paramount design consideration. Williams (1985) determined that the primary consideration of grid cell size for LESA implementation is the minimum parcel size used by the SA subsystem of LESA. The limiting factor, as determined by the SA portion of LESA, is the 2 acre plot size designated for rural growth areas. Williams used instead, a compromise 2.5 acre parcel size (100 by 100 meters) because of the ease with which the cell size would fit within the UTM grid system.

Even had Williams used the 2 acre parcel size for his GIS implementation, sampling theory indicates a necessarily finer resolution than that of the limiting parcel size itself. Indeed, Shannon and Weaver (1949) suggest that the size of the sampling unit used (the grid cell in this case) should be less than 1/2 the size of the smallest item upon which one wishes to operate. This would have required Williams to use a cell size of less than 70 meters on a side. If this resolution had been used, it is not known how the outcome of the agricultural LESA model might have been affected. Within the context of the forest LE model the same limiting 2 acre parcel size must necessarily be given consideration if the outcome is to be amenable to merger with a SA subsystem. Therefore, a number of resolutions, both larger and smaller than the 2.5 acre parcel size used by Williams (1985), are used here to test the sensitivity of the forest LE procedures to such manipulation.

LITERATURE REVIEW

A major issue in designing any GIS model is the selection of proper input scale in a vector system or grid cell resolution in a raster-based system. The latter is the focus of this research. Previous research has shown that coarser resolution lowers the categorical accuracy of the resultant database (Wehde, 1982). Wehde used an iterative regrouping of cells already digitized to achieve a progressively coarser resolution. Although an important contribution to error analysis in raster-based GIS, Wehde's re-aggregating method of arriving at coarser resolution will not always produce the same category percentages as are achieved through primary data input at selected resolutions. Variable input resolutions are in part determined by the method of cell classification, i.e., centroid of cell, percentage of cell, dominant type or presence/absence. Resolution may also be determined by boundary configuration. As Crapper (1984) points out, uncertainty in thematic classification near boundaries is frequently an artifact of the number of boundary cells. Perhaps more importantly, and as Gershmehl and Napton (1982) state, data used in a grid cell GIS for cell classification and retrieval "... must be gathered in a way that is reliable in the particular, not in the aggregate." It is the reliability of the data as quantized into selected cell sizes for analysis that is at issue here.

One naturally assumes that if there is a reduction in categorical accuracy, whether in the particular or the aggregate, there will be a subsequent reduction in accuracy of the product of any analysis performed with that database. This has not been proven to be the case. Gersmehl and Brown (1987), analyzing the data requirements, including grid cell resolution, for regional scale water resource analysis projects, concluded that the ideal cell size depends on the interaction among study area characteristics, relatability among other data files, and the specific analytical operations performed on the data. In one specific application of raster-based GIS to assess soil erosion and sediment deposition, Gersmehl (1987) determined that a refinement in cell size would not be a high priority under the model's conditions.

This conclusion may or may not be valid for other applications. Depending on the data inputs, methods of data analysis, and desired results, the resolution may be relatively unimportant, as in the case of soil erosion modeling (Gersmehl, 1987), or it may be absolutely essential. Important applications of GIS to automate existing policy support mechanisms such as the LESA model need prior determination of the relevant factors and cell resolutions necessary for meaningful results. The present prototype is designed to establish these relevant factors and necessary resolutions for implementation of the LE subsystem procedures for forestry within the SCS's LESA model.

PROCEDURE

Software

The software used in this prototype (OSU-MAP-for-the-PC) is a raster-based system which originally required all map layers to be archived as maps. This version of the software was limited to 99 map layers, with a maximum of approximately 50,000 — 60,000 cells. A newer version is already available that treats each map as a separate data base that can be archived on separate disks.

Other microcomputer packages, such as IDRISI, allow much larger data bases to be developed, depending largely on the amount of memory and storage capabilities of the computer. Most of these systems also require that each map layer be archived. As such, large quantities of computer space can be taken up quickly, especially if there are a great many cells.

Certainly, for operational GIS, considerations of resolution within a database as small as that used in this prototype will have little impact on database design. If, however, the LESA model were implemented on a county-wide basis, which is generally what has happened with LESA models, then the increased volumes of data needed at finer resolutions would play a role in design. Vector systems will also have to contend with data volumes as determined by input scale. However, the input scale in vector systems will probably be dictated by the 1:20,0000 scale of soil survey maps used in LESA modeling.

Source Data

LE subsystem procedures for forestry are based on soil survey information, both mapped and tabular, together with ancillary information from the SCS National Forestry Manual (1977) and the SCS Soils-5 forms (SCS, 1983). For this particular study the initial GIS database was produced by manually digitizing soil map information from sheet 31 of the Hanover County, Virginia, soil survey (Hodges et al., 1976). This particular area was selected partly because Hanover County has a completed forest LE. Sheet 31 was selected because of its proximity to the SCS office for Hanover County and its relatively large variety of soil types within the small area.

The soils were digitized using manual cell by cell encoding of the dominant percentage type of soil for each cell, a technique recommended by Tomlin and Tomlin (1981). Centered roughly on the town of Hanover, the study area has dimensions of 9,000 feet horizontally by 12,000 feet vertically for a total area of 108,000,000 square feet. These particular dimensions were selected to allow a wide variety of resolutions at which to sample the data.

For analysis four cell resolutions were selected: 100, 200, 300, and 600 feet on a side. With these resolutions each data layer has 600, 1,200, 2,700, and 10,800 cells, respectively. Additionally, the 100 foot (0.23 acre) and 200 foot (0.92 acre) cell sizes are smaller than that used by Williams, while the 300 foot (2.07 acres) cell size is a good approximation of Williams' original 100 meter (2.5 acres) cell size, and the 600 foot (8.26 acres) cell size is substantially larger than that used in his study. This provides a wide range of cell sizes upon which to determine the impact of progressively larger resolutions on the analytical results.

Automated Land Evaluation Procedures

The development of LE values for the cells in each of the models is based on the mathematical addition of land rating element values interpreted from each of four charts found in the SCS LESA manual (1983) (Figure 1). Each of these charts, numbered 1-A through 1-D produces a required informational layer based on reclassifying the soils according to selected parameters. To equate the maps produced from GIS renumbering of soils maps to the charts used for this purpose (charts 1-A through 1-D), the maps produced during each re-classification operation were named "1-AMAP," "1-BMAP," "1-CMAP," and "1-DMAP," respectively (Figure 2).

Chart 1-A (Figure 1) produces productivity ratings based on values for cumulative mean annual increment (CMAI) of lumber produced in cubic feet/acre for a single pre-selected indicator tree species. The indicator tree is determined by the regional SCS forester and the evaluation of CMAI is based on known forest growth productivity values for the regional soils. The following procedure is used: First, the site index values for each soil are taken from the soil survey tables. Then the productivity class is determined by comparison with charts VA537-1 through VA537-7, which are available from the SCS (Norman Wilson, personal communication). The CMAI is calculated by multiplying the productivity class by 14.3 cubic feet per acre, which is an empirical value used by the SCS. The CMAI value is then compared to chart 1-A to determine the productivity rating. Within the digital database the soils map layer is renumbered to correspond to the values assigned through chart 1-A, thus producing map layer 1-AMAP. This map layer represents the productivity of each species on each soil for forest

FOREST LAND - RATING ELEMENTS

Chart 1-A

Culmination of mean annual increment cu ft/acre	Rating
> 180	1.0
160 - 179	0.9
140 - 159	0.8
120 - 139	0.7
100 - 119	0.6
80 - 99	0.5
60 - 79	0.4
40 - 59	0.3
20 - 39	0.2
< 20	0.1

Chart 1-B

Indicator tree species	Rating
loblolly pine	1.0
yellow poplar	0.9
shortleaf pine	0.8
northern red oak	0.7
white oak	0.6
sweetgum	0.4
virginia pine	0.3

CHART 1-C

SLOPE %	Rating
0-15 (0-7)*	1.0
15-25 (7-15)*	0.8
25-35 (15-25)*	0.6
35-50 (>25)*	0.4
50+ (NA)*	0.1 (NA)

* Coastal Plain or Piedmont

CHART 1-D

Soil Characteristic	Rating
No limitations	1.0
Fragmental / skeletal	NA
Sandy/aeric subgroups	0.5
Clayey (sandy)	0.4
Stoniness (aquults/toxic)	0.2
Wetness or ponding	0.1
Shallow or droughty	0.1

FIGURE 1. Rating Elements for Forest Land Evaluation (LE) (adapted from SCS, 1983).

wood production. It should be noted that OSU-Map-for-the-PC only supports integer mathematics so all rational numbers used were multiplied by 10 to allow the values to be calculated.

Chart 1-B (Figure 1) is used to determine the tree species rating based on the desirability of a number of SCS selected species commonly occurring in the county. To do this, the soils data layer is renumbered based on the indicator species for each soil type found in the soil survey manual. For example the soil survey report might show that a given soil polygon (type) is best suited for yellow poplar of all the trees occurring in the region. Because chart 1-B shows yellow poplar to have an indicator tree species rating of 0.9, the soil polygon is renumbered to 0.9. All soil polygons are thus renumbered, and the final map layer is labeled 1-BMAP.

Chart 1-C (Figure 1) determines a steepness of slope rating based on the estimated slope determined in the field and published in the soil survey. Renumbering the soil map layer to correspond to the slope ratings, ranging from 0.6 to 1.0 in this particular study area, produces a map which shows the slope ratings for each cell (1-CMAP).

Chart 1-D (Figure 1) produces a soil limitation rating. The limitation information is derived from the classifications of the soils (i.e., aquults and aeric subgroups) and from the soil survey text, which indicates tendencies toward seasonal flooding and ponding and possible droughty conditions, as well as soils which are too sandy. For Hanover County these values range from 0.1 to 1.0. The final map for soil limitation rating is named 1-DMAP.

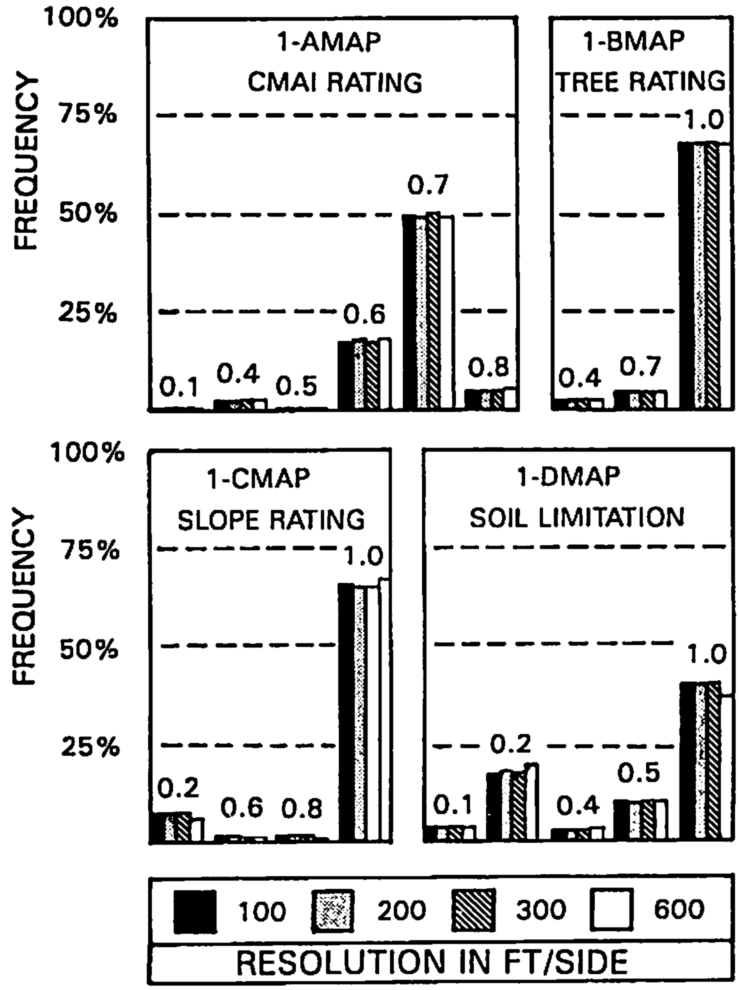

FIGURE 2. Percentages of Land Evaluation (LE) Rating Elements Calculated at Different Resolutions.

The information necessary to produce maps 1-AMAP through 1-DMAP is incomplete as derived from the soil survey. It was necessary to consult the district conservationist (George Ways, personal communication) and the district SCS forester (Norman Wilson, personal communication) to complete the charts (Table 1).

Once maps 1-AMAP, 1-BMAP, 1-CMAP, and 1-DMAP were produced, a map called TOTAL was created by adding these four maps together. This produced a set of values having a maximum possible value of 40 (4.0 in the LESA model). The possible value is ten times that which is indicated by the LESA model because the GIS used does not support floating point mathematics.

Within this study area the maximum value produced was 37 (3.7 in the LESA model). This value was used to re-calibrate the composite map TOTAL to produce a map of relative composite values called LE-MAP which shows a value of 100 for 37 and correspondingly lower values for all of the remaining numbers. This was performed by multiplying all of the map's values by 100 and then dividing by the maximum value of 37. Once again the additional step of multiplying by 100 was used to account for the lack of floating point mathematics in the software.

TABLE 1. Comparison of Soil Values and Land Evaluation (LE) Component Values

Soil Symbol	Chart 1-A	Chart 1-B	Chart 1-C	Chart 1-D	Total	Relative Composite
02	0.7	1.0	1.0	1.0	3.7	100
09	0.7	1.0	1.0	1.0	3.7	100
23	0.7	1.0	1.0	1.0	3.7	100
56	0.7	1.0	1.0	1.0	3.7	100
67	0.7	1.0	1.0	1.0	3.7	100
33b	0.7	1.0	1.0	1.0	3.7	100
25b	0.7	1.0	1.0	1.0	3.7	100
54b	0.7	1.0	1.0	1.0	3.7	100
55b	0.7	1.0	1.0	1.0	3.7	100
77	0.6	1.0	1.0	1.0	3.6	97
39b	0.6	1.0	1.0	1.0	3.6	97
12b	0.6	1.0	1.0	1.0	3.6	97
40b	0.6	1.0	1.0	1.0	3.6	97
63b	0.6	1.0	1.0	1.0	3.6	97
47b	0.6	1.0	1.0	1.0	3.6	97
70c	0.7	1.0	0.8	1.0	3.5	95
69c	0.7	1.0	0.8	1.0	3.5	95
08	0.8	1.0	1.0	0.5	3.3	89
70d	0.7	1.0	0.6	1.0	3.3	89
24	0.7	1.0	1.0	0.5	3.2	86
43	0.7	1.0	1.0	0.5	3.2	86
57b	0.7	1.0	1.0	0.4	3.1	84
70b	0.1	1.0	1.0	1.0	3.1	84
64b	0.6	1.0	1.0	0.4	3.0	81
18	0.7	1.0	1.0	0.2	2.9	78
28	0.7	1.0	1.0	0.2	2.9	78
46	0.7	1.0	1.0	0.2	2.9	78
70e	0.7	1.0	0.2	1.0	2.9	78
70f	0.7	1.0	0.2	1.0	2.9	78
37	0.4	0.4	1.0	0.1	2.8	76
73	0.6	1.0	1.0	0.2	2.8	76
16	0.8	0.7	1.0	0.2	2.7	73
10b	0.5	1.0	1.0	0.1	2.6	70
30	0.4	0.4	1.0	0.1	1.9	51

The final map was produced through implementation of the following formula:

LE-MAP = (TOTAL * 100MAP) / 37

where:

100MAP = A MAP OF CELLS ALL EQUAL TO 100

and:

TOTAL = 1-AMAP + 1-BMAP + 1-CMAP + 1-DMAP

The values from LE-MAP map were tabulated for each of the implementations and then sliced into equal class intervals for final display, resulting in five categories of LE values ranging from a low of 51 to a high of 100.

Analysis

The results of these LE models were analyzed four times, each under conditions of the different selected resolutions. The numbers, percentages, and values of cells coded for each

TABLE 2. Comparison of Soil Value Percentages at Different Resolutions Listed by Decreasing Land Evaluation (LE) Score

Soil Symbol	RES: 100 CELLS	RES: 100 %	RES: 200 CELLS	RES: 200 %	RES: 300 CELLS	RES: 300 %	RES: 600 CELLS	RES: 600 %
water	2698	24.98	677	25.07	299	24.92	76	25.33
02	276	2.56	66	2.44	33	2.75	4	1.33
08	29	0.27	7	0.26	4	0.33	2	0.67
09	172	1.59	43	1.59	19	1.58	5	1.67
16	480	4.44	120	4.44	53	4.42	13	4.33
18	894	8.28	239	8.85	97	8.08	28	9.33
23	1379	12.77	333	12.33	155	12.92	40	13.33
24	49	0.45	11	0.41	4	0.33	0	0.00
28	28	0.26	7	0.26	3	0.25	1	0.33
30	91	0.84	24	0.89	8	0.67	3	1.00
37	180	1.67	41	1.52	22	1.83	5	1.67
43	1024	9.48	251	9.30	115	9.58	30	10.00
46	381	3.53	97	3.59	46	3.83	14	4.67
56	56	0.52	13	0.48	5	0.42	2	0.67
67	12	0.11	3	0.11	1	0.08	0	0.00
73	99	0.92	28	1.04	13	1.08	3	1.00
77	655	6.06	165	6.11	71	5.92	21	7.00
39b	44	0.41	13	0.48	5	0.42	2	0.67
10b	49	0.45	12	0.44	6	0.50	1	0.33
12b	52	0.48	13	0.48	6	0.50	2	0.67
33b	15	0.14	3	0.11	1	0.08	0	0.00
40b	107	0.99	28	1.04	11	0.92	2	0.67
25b	324	3.00	75	2.78	36	3.00	7	2.33
63b	20	0.19	6	0.22	2	0.17	1	0.33
47b	15	0.14	4	0.15	2	0.17	0	0.00
70c	125	1.16	31	1.15	12	1.00	1	0.33
70e	472	4.37	122	4.52	52	4.33	12	4.00
57b	18	0.17	4	0.15	2	0.17	0	0.00
64b	288	2.67	70	2.59	32	2.67	10	3.33
54b	51	0.47	13	0.48	4	0.33	0	0.00
70f	277	2.56	72	2.67	35	2.92	5	1.67
70d	154	1.43	39	1.44	15	1.25	3	1.00
69c	27	0.25	7	0.26	4	0.33	1	0.33
55b	249	2.31	59	2.19	26	2.17	6	2.00
70b	10	0.09	4	0.15	1	0.08	0	0.00
TOTAL	10800	100	2700	100	1200	100	300	100

SOILSMAP at each resolution were tabulated (Table 2), and those produced under each of the interim maps 1-AMAP through 1-DMAP, as well as those produced in the final LE-MAP products, were tabulated and graphed for visual comparison (Tables 3–7, Figures 2 and 3).

RESULTS

The digitized soils values for small representative parcels diminished as the cell size increased. At resolution 600, seven of the soils categories — Dunbar fine sandy loam, Udifluvents, Goldsboro fine sandy loam, Norfolk fine sandy loam, Pamunkey Variant gravely sandy loam, Pamunkey loamy sand, and the gently sloping Udults-Ochrepts complex (with the corresponding map symbols 24, 67, 33b, 47b, 57b, 54b, and 70b) — completely disappeared (Table 2). Examination of the tables (Tables 3–7) and graphs (Figure 2) for the interim mapped data for 1-AMAP through 1-DMAP shows little impact from the loss of these small soil parcels. Instead, a strikingly similar percentage of each group appears at all resolutions.

TABLE 3. Comparison of 1-AMAP Value Percentages at Different Resolutions

1-AMAP

CATEGORY	RES: 100 CELLS	%	RES: 200 CELLS	%	RES: 300 CELLS	%	RES: 600 CELLS	%
WATER	2698	24.98	677	25.07	299	24.92	76	25.33
cmai=.1	10	0.09	4	0.15	1	0.08	0	0.00
cmai=.4	271	2.51	65	2.41	30	2.50	8	2.67
cmai=.5	49	0.45	12	0.44	6	0.50	1	0.33
cmai=.6	1895	17.55	484	17.93	208	17.33	54	18.00
cmai=.7	5368	49.70	1331	49.30	599	49.92	146	48.67
cmai=.8	509	4.71	127	4.70	57	4.75	15	5.00
TOTAL	10800	100	2700	100	1200	100	300	100

"CMAI" is the cumulative mean annual increment of lumber produced in cubic feet/acre. Percentages are those of the total map occupied by each category.

Close examination of the excluded soils shows that their relative composite LE scores ranged from 84 to 100, with three of them having a value of 100. Alternatively, the two soils which exhibited the lowest LE scores, soil type 30 (Forestdale loam) with an LE score of 51, and soil type 10b (Bourne fine sandy loam) with an LE score of 70, show little LE score variation with cell size. This may be a locational or directional artifact, or merely digitizing error because they do not frequently occur either. It does show, however, that there are few soils in the study area which can be classified as having low LE scores.

Because the majority of the soils in this region receive relatively high LE scores, the loss of the seven aforementioned soils will have little impact on the overall percentages of soils for each category range. Additionally, because each interim map shows such a striking percentage similarity from one resolution to the next, it is obvious that the renumbering procedures produce highly generalized values for LE, even though there is a high number of soils types from which these values were derived. Final LE scores, for example, show the same pattern of classification similarity from one resolution to the next, with only one LE value (LE = 83) disappearing. Furthermore, once these LE scores are grouped into five categories, the similarity among resolutions appears most pronounced (Figure 3), and when displayed cartographically, result in nearly identical spatial distributions as well (Figure 4).

The four resolutions used in this study produced radically different volumes of data. Resolution 100, for example, required over 320 kilobytes of storage just for the map data and

TABLE 4. Comparison of 1-BMAP Value Percentages at Different Resolutions

1-BMAP

CATEGORY	RES: 100 CELLS	%	RES: 200 CELLS	%	RES: 300 CELLS	%	RES: 600 CELLS	%
WATER	2698	24.98	677	25.07	299	24.92	76	25.33
TR = .4	271	2.51	65	2.41	30	2.50	8	2.67
TR = .7	480	4.44	120	4.44	53	4.42	13	4.33
TR = 1.0	7351	68.06	1838	68.07	818	68.17	203	67.67
TOTAL	10800	100	2700	100	1200	100	300	100

"TR" is the tree species rating for each soil type. Percentages are those of the total map occupied by each category.

TABLE 5. Comparison of 1-CMAP Value Percentages at Different Resolutions

1-CMAP

CATEGORY	RES: 100 CELLS	%	RES: 200 CELLS	%	RES: 300 CELLS	%	RES: 600 CELLS	%
WATER	2698	24.98	677	25.07	299	24.92	76	25.33
SR = .2	749	6.94	194	7.19	87	7.25	17	5.67
SR = .6	154	1.43	39	1.44	15	1.25	3	1.00
SR = .8	152	1.41	38	1.41	16	1.33	2	0.67
SR = 1.0	7047	65.25	1752	64.89	783	65.25	202	67.33
TOTAL	10800	100	2700	100	1200	100	300	100

"SR" is the slope rating for each soil type. Percentages are those of the total map occupied by each category.

their associated values, roughly filling a standard personal computer (PC) floppy disk. By contrast, the resolution 600 database required less than 17 kilobytes of storage. This means that very large areas could be stored and analyzed within a PC-based GIS if one could use the much larger cell size.

Alternatively, because the data volumes described contain a large number of interim maps which might be deleted, the necessary computer disk space could be reduced dramatically. The maps which are used for analysis could also be converted to a batch file, a set of commands which can be stored and later called upon to create the needed maps. This latter approach would require only the storage of the necessary source maps from which the LESA maps could be produced, thus limiting the space requirements to these originals and the maps resulting from a given analysis.

CONCLUSION

The forest LE procedures have been shown to be readily adaptable to automation within a GIS. Procedurally, the model requires only an additive compilation of renumbered maps based on the soil survey information provided. Such a system requires the assistance of local SCS officials who are most familiar with local soils, and who can provide needed insights before map renumbering can take place.

TABLE 6. Comparison of 1-DMAP Value Percentages at Different Resolutions

1-DMAP

CATEGORY	RES: 100 CELLS	%	RES: 200 CELLS	%	RES: 300 CELLS	%	RES: 600 CELLS	%
WATER	2698	24.98	677	25.07	299	24.92	76	25.33
SL = .1	427	3.95	105	3.89	47	3.92	11	3.67
SL = .2	1882	17.43	491	18.19	212	17.67	59	19.67
SL = .4	306	2.83	74	2.74	34	2.83	10	3.33
SL = .5	1102	10.20	269	9.96	123	10.25	32	10.67
SL = 1.0	4385	40.60	1084	40.15	485	40.42	112	37.33
TOTAL	10800	100	2700	100	1200	100	300	100

"SL" is the soil limitation rating based on the physical limitations of each soil type. Percentages are those of the total map occupied by each category.

TABLE 7. Comparison of Land Evaluation (LE) Score Percentages at Different Resolutions

	RES: 100		RES: 200		RES: 300		RES: 600	
CATEGORY	CELLS	%	CELLS	%	CELLS	%	CELLS	%
WATER	2698	24.98	677	25.07	299	24.92	76	25.33
LE=100	2534	23.46	608	22.52	280	23.33	64	21.33
LE=97	786	7.27	201	7.44	86	7.17	26	8.67
LE=94	27	0.25	7	0.26	4	0.33	1	0.33
LE=91	125	1.16	31	1.15	12	1.00	1	0.33
LE=89	183	1.69	46	1.70	19	1.58	5	1.67
LE=86	1073	9.94	262	9.70	119	9.92	30	10.00
LE=83	10	0.09	4	0.15	1	0.08	0	0.00
LE=81	306	2.83	74	2.74	34	2.83	10	3.33
LE=78	1580	14.63	415	15.37	181	15.08	48	16.00
LE=75	571	5.29	150	5.56	65	5.42	15	5.00
LE=72	587	5.44	148	5.48	64	5.33	15	5.00
LE=70	49	0.45	12	0.44	6	0.50	1	0.33
LE=51	271	2.51	65	2.41	30	2.50	8	2.67
TOTAL	10800	100	2700	100	1200	100	300	100

"LE" is the composite land evaluation score based on the addition of all values for 1-AMAP, 1-BMAP, 1-CMAP and 1-DMAP. Percentages are those of the total map occupied by each category.

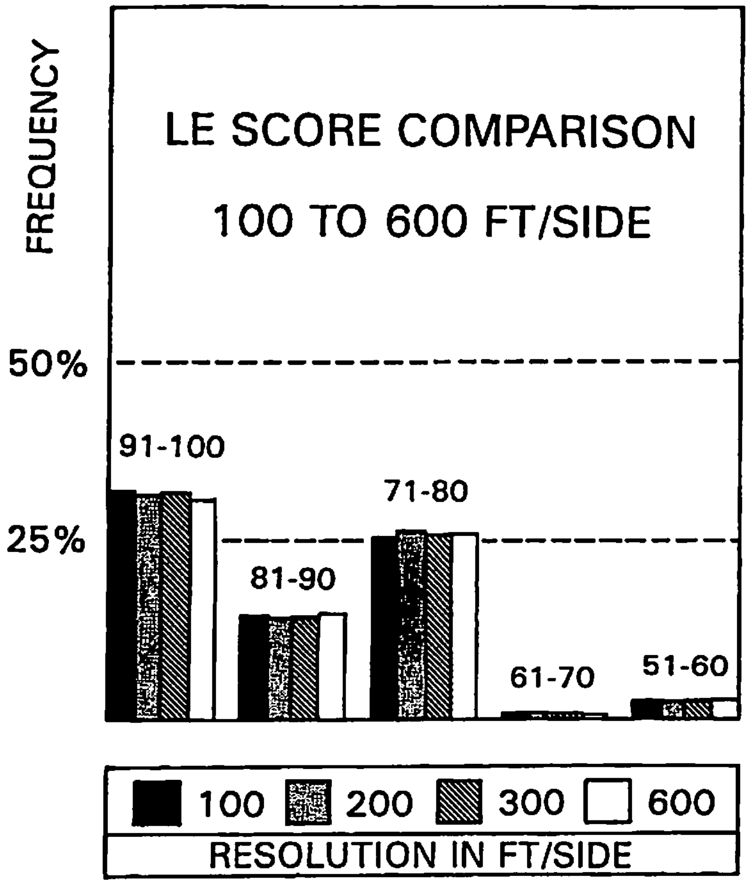

FIGURE 3. Final Land Evaluation (LE) Score Comparisons at Different Resolutions (from Table 7).

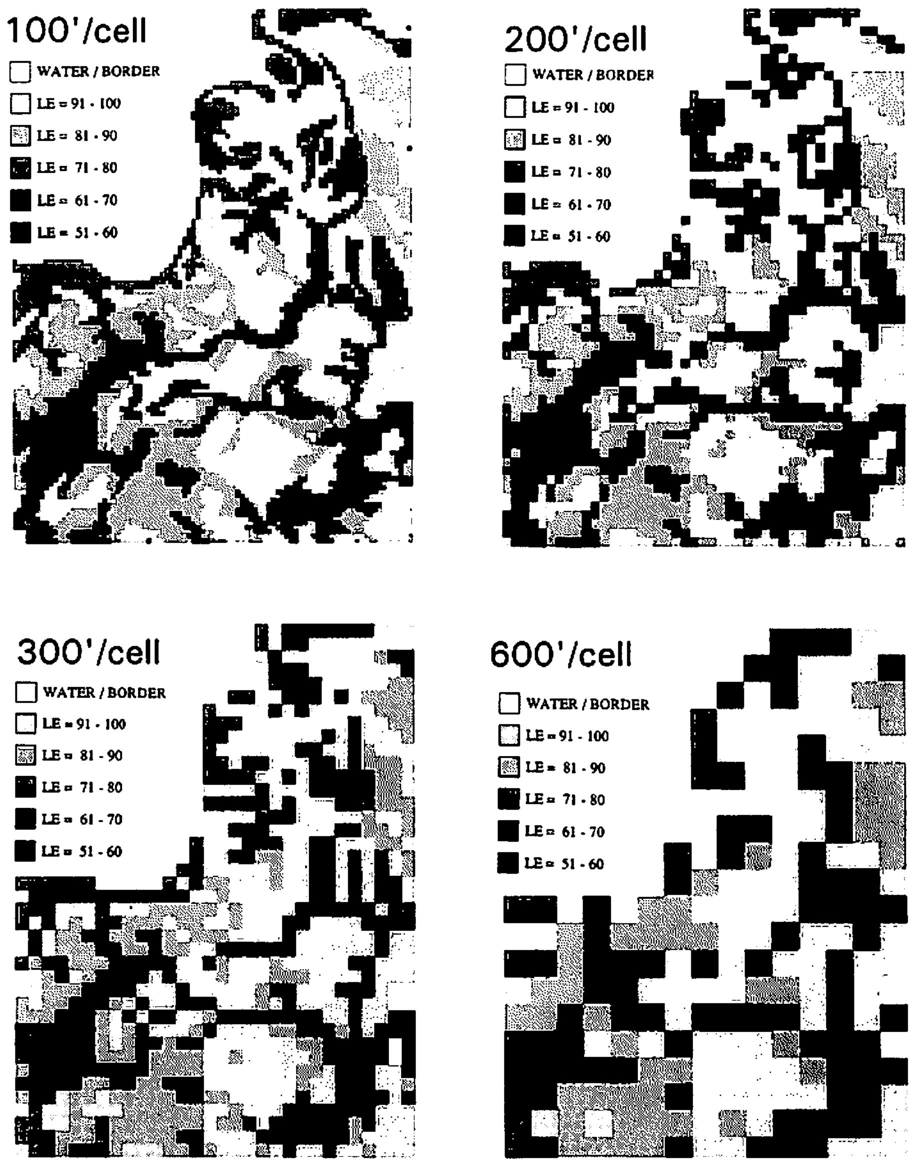

FIGURE 4. Map Output for Land Evaluation (LE) Scores at Different Resolutions.

The attempt to identify a proper cell size for modeling based on large scale loss of information due to resolution change failed. All variables show a nearly identical degree of LE score frequency, no variable deviating more than 2–3% no matter what cell size was used. Additionally, the interim maps (1-AMAP through 1-DMAP) did not show any significant deviation from this trend. It appears from this study that, at least within the resolution variance of from 100 foot cells to 600 foot cells, and within this study area, no significant change in the LE category percentages will occur, although minor fluctuations will be observed. This requires that the selection of resolution for such a forest LE subsystem be based, as Williams demonstrated, on the smallest portion of land necessary to implement the SA factors — that is, the 2 acre cell size for rural land use.

This minimum unit size should be used, however, not as the smallest cell to be coded, but rather as the smallest cell which must be observed. As such, a cell size of less than 1/2 the 2 acre minimum should be used to conform to the theoretical considerations of the sampling theorem. A smaller cell size will result in finer detail, the ability to analyze smaller land parcels, and a larger database for any area modeled.

If batch files were used, rather than archiving each map as it is produced, the amount of data which could be stored could easily encompass whole counties or regions, depending on the software limitations. Furthermore, once disk space is not a limiting factor, a cell size substantially smaller than the 2 acre minimum required by the SA portion of LESA could be used, thus assuring that small parcels of land will not be eliminated from the study, satisfying the requirements of the sampling theorem, and allowing ready merger of the LE subsystem into the LESA model.

Acknowledgments: I would like to thank Mr. George Ways, District Soil Conservationist for Hanover County, Virginia, and Mr. Norman Wilson, District SCS Forester for Hanover County for their invaluable assistance on this project.

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