vegetation. Soil characteristics in these geographical subunits will clearly influence vegetation recovery; these relationships are being explored in ongoing research.

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A Computer-generated Soils Map of Santa Cruz Island, California

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Abstract - A soil map of Santa Cruz Island (249 km^2) was constructed based on a field soil survey and data in a geographic information system (GIS) of the island. Soil map units were determined from 138 classified soil profiles generalized using a dasymetric approach based on an overlay of the registered GIS image planes of geologic substrate and vegetation. Nearly 60% of the island is covered by the three largest mapped units, representing soils on volcanics and volcaniclastics under grass and oaks, and soils on the Monterey formation under grass. Eleven subgroups of the USDA Soil Taxonomy (Soil Survey Staff 1975) occur in the large area of island volcanics under grass (37% of the island) and soil spatial variability is high, with two or three subgroups occurring in a single 2.25 ha grid cell of the map. However, the southwest corner of the island has the most heterogeneous soils (14 subgroups) and the greatest soil spatial variability, with four or more subgroups occurring in a single grid cell. The use of a GIS permits rapid generalization of map units from sampled points, but the rules used for generalization were simplistic, based only on geologic substrate and vegetation, which in turn were mapped at a coarse spatial resolution (150 m). It is difficult to compare the accuracy of the technique to that of a standard soil survey, because no standard soil survey exists for the island. Soils not identified in map unit names are estimated to cover less than 25% of the area of any map unit. However, the gridded format means that soil unit boundaries are poorly defined and therefore the map has limited field utility. Nevertheless this map provides a broad overview of the nature and distribution of Santa Cruz Island soils while illustrating a method whereby computerized data could be utilized in soil mapping.

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Introduction

The purpose of this study was to construct a soil map of Santa Cruz Island, based on a field soil survey (Butterworth *et al.* 1993) and a geographic information system (GIS) of the island. No soils map currently exists for the island, but some soils have been described and classified by Brumbaugh (1980, 1983). Soil surveys have been completed for some of the other California Islands, notably San Nicolas and San Clemente (U.S. Department of Agriculture 1985a, b) and soils on Santa Barbara, San Miguel and San Clemente Islands have been described and analyzed by W. Allardice (pers. comm.), Johnson (1979, 1980) and Muhs (1982).

A computerized approach was selected for mapping because of the large size (249 km^2) and relative inaccessibility of the island, which has rugged relief and few roads. The project was a test of the utility of a dasymetric approach to mapping using computerized geographical data as a tool for soil map unit generalization in remote areas, similar to that suggested by Fisher (1988). Data for the GIS layers and the soil map were collected as part of a larger ongoing project to construct a GIS of the natural resources of Santa Cruz Island (see Butterworth *et al.* 1992; Jones *et al.* 1993).

Methods

Soil mapping is the process of extending point observations of soils to areas of the same kinds of soils, based on sampling, classification, map unit definition and generalization using mapping rules (Soil Survey Staff 1980). Our procedure differed from standard soil survey and mapping in three respects. First, the number and location of soil profile sampling points were chosen proportional to the area covered by vegetation and geologic substrate classes, which in turn were determined using the GIS (Table 1). Second, the map units were defined according to the proportions of subgroups from the USDA Soil Taxonomy (Soil Survey Staff 1975) represented by sampled soil profiles, rather than by identifying associations or complexes. Third, layers of data in the GIS were overlaid and a simplistic mapping rule based on theories of soil genesis was used to generalize from points to map areas. A fundamental tenet of soil genesis attributes soil formation to the interacting effects of five soil forming factors; climate, vegetation and biota; relief; parent material and time (Jenny 1984). Our field observations indicated a close relationship of soil morphology to vegetation, geologic substrate, slope angle and aspect (Butterworth *et al.* 1993; Jones *et al.* 1993). This provided the basis for our mapping rule: that meaningful map units of soil taxa on the island could be constructed using data on these factors mapped at a scale of 1:24 000 and digitized in 150 x 150 m grid cells. Geologic substrate and vegetation data were most important but GIS data on slope angle and aspect also were used in this process.

GIS Data and Image Layers: At present, the GIS is simply a computerized data set of geographic characteristics of Santa Cruz Island. It consists of 10,839 spatially referenced cells, each covering an area of 150 x 150 m (2.25 ha) on the ground. For each cell (designated by its line and sample number) the GIS contains the following information, arranged in "layers": ecological zone; elevation; slope angle*; exposure*; geologic substrate*; geologic features; ironwood (*Lyonothamnus floribundus* subsp. *asplenifolius*) and vegetation.*

The GIS layers marked with an asterisk (*) were used to map soils. Elevation and exposure were interpreted directly from 1:24,000 U.S. Geological Survey 7.5 minute topographic quadrangles (USGS 1943) overlaid with a 0.64 cm (0.25 inch) grid. Slope angles were calculated from the elevation data. Geologic substrate and geologic features were interpreted directly from the map of Santa Cruz Island geology (Weaver *et al.* 1969) overlaid with the same grid, and locations of groves of ironwood were mapped by Junak (1987). The vegetation layer was digitized using the same grid overlaid on a vegetation map of the island (Jones *et al.* 1993).

The GIS exists in two forms: 1) digitized data on file on the Geography VAX 750 computer at the University of California, Santa Barbara and 2) as images (Figs. 1-4). To create the image layers, column vectors each containing the coordinates and one data layer (*i.e.*, geologic substrate, vegetation, elevation, exposure) were converted to raster (*i.e.*, digital image) format with image processing software developed by J. Dozier and J. Frew and software programs developed by R. Crippen at the University of California, Santa Barbara.

Before soil sampling was conducted, the raw data on exposure, slope angle, geologic substrate and vegetation were recoded into generalized categories using the Earth Resources Data Analysis System (ERDAS™). Exposure, originally encoded in 10° increments, was recoded into 4 categories: north, south, east and west (Fig. 1). Slope angle, originally encoded in degrees, was grouped into three categories: 0-3°; 4-12° and >12° (Fig. 2). Weaver & co-author's (1969) original 20 units for geologic substrate were reduced to nine by grouping formations with similar age and mineralogy, and by including Quaternary alluvium, terrace gravel and landslides in the geologic substrate surrounding them (Renwick *et al.* 1982). Indian middens were separated into a tenth substrate class, but are smaller than the grid cell size and therefore do not appear on the substrate image (Fig. 3, Table 1). The vegetation layer (Fig. 4) included 11 vegetation types mapped as described by Jones & co-authors (1993). Cross-tabulated statistics from these layers were used to determine the proportions of soil profiles to be sampled in various parts of the island (Table 1).

Map Units and Generalization: To define preliminary soil map units, the registered image planes of substrate, vegetation, slope and aspect were overlaid in pairs (Fig. 5). Two types of co-occurrence information were obtained for each pair using an ERDAS™

Table 1. Numbers of soil profiles sampled according to geology and vegetation type on Santa Cruz Island.

Vegetation	Geologic Substrate												
	SCI volcanics, intrusives	SCI schist, Alamos plutonite, Willows diorite	Monterey formation	Blanca volcani-clastics	Canada, Pozo formation	Rincon formation	San Onofre breccia	Cozy Dell formation	Vaqueros, Jolla Vieja sandstone	midden	TOTAL	% of sample	% of island[a]
grass	24	10	13	7	6	3	3	3	3	2	74	54	52
oaks	7	3	4	1	–[b]	–	–	–	–	–	15	11	5
coastal sage	3	1	3	5	2	1	–	–	–	–	15	11	5
chaparral	6	8	4	–	–	–	1	–	–	–	19	13	18
pines	2	2	–	–	–	–	–	–	–	–	4	3	2
bare	–	1	1	–	–	1	1	–	–	–	4	3	10
riverine	2	3	–	1	1	–	–	–	–	–	7	5	7
other[c]	–	–	–	–	–	–	–	–	–	–	0	0	1
TOTAL	44	28	25	14	9	5	5	3	3	2	138		
% of sample	32	20	18	10	6	4	4	2	2	2		100	–
% of island	49[d]	14	17[d]	12	2	1	2	1	2	(1-3)[e]		–	100

[a] Calculated from GIS data as described in Jones & co-authors (1993).
[b] Not sampled.
[c] Woody exotics, ironwood and coastal bluff vegetation.
[d] About 13% of the island consists of Quaternary alluvium, landslides and terrace gravels. For soil sampling and mapping purposes, these were divided between the SCI volcanics and Monterey formation substrates, on which they principally occur.
[e] Middens are estimated to cover 1-3% of the island, but no middens were large enough to occupy a grid cell on the island GIS; thus they were not counted.

Table 2. Soil mapping units assigned as a function of geology and vegetation on Santa Cruz Island. Units are defined in the text.

Vegetation	Geologic Substrate								
	SCI volcanics	SCI schist, Alamos plutonite, Willows diorite	Monterey shale	Blanca volcani-clastics	Canada, Pozo shale	Rincon shale	San Onofre breccia	Cozy Dell shale	Vaqueros, Jolla Vieja sandstone	midden
grass	A	C	F	H	I	J	J	K	K	M
oaks	B	C	G	H	n/a	n/a	n/a	n/a	n/a	M
coastal sage	A	D	G	H	I	n/a	K	K	K	M
chaparral	B	E	G	H	I	J	K	n/a	K	M
pines	D	D	G	H	n/a	n/a	n/a	n/a	n/a	M
bare	A	D	G	H	I	J	K	K	K	M
riverine	L	L	L	L	L	L	L	L	L	L
other	B	n/a	G	n/a	n/a	n/a	n/a	n/a	n/a	n/a

n/a This vegetation and geology combination does not occur on the island.

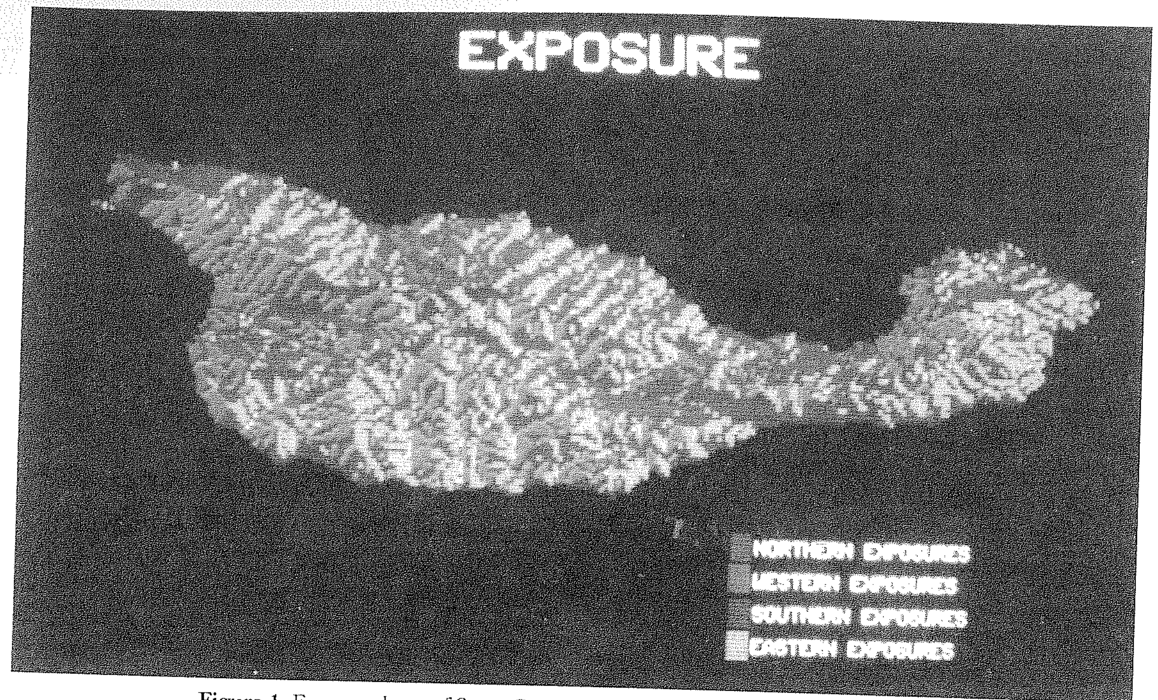

Figure 1. Exposure layer of Santa Cruz Island GIS used for soil map construction.

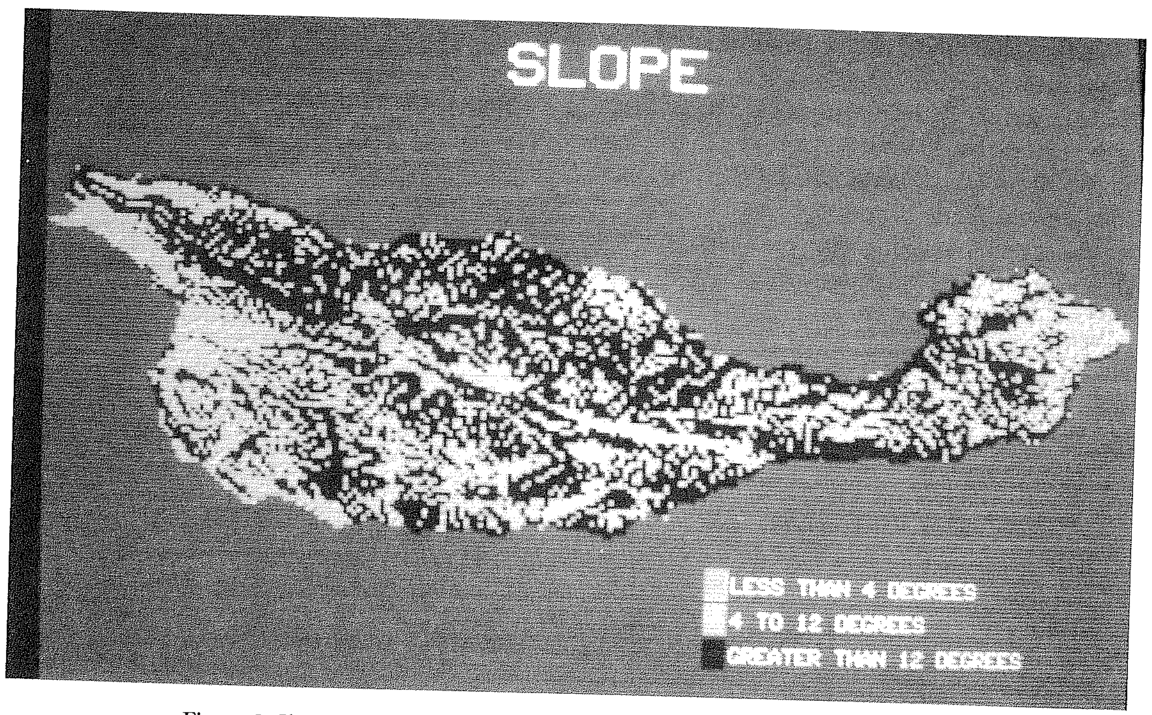

Figure 2. Slope angle layer of Santa Cruz Island GIS used for soil map construction.

Figure 3. Geologic substrate layer of Santa Cruz Island GIS used for soil map construction.

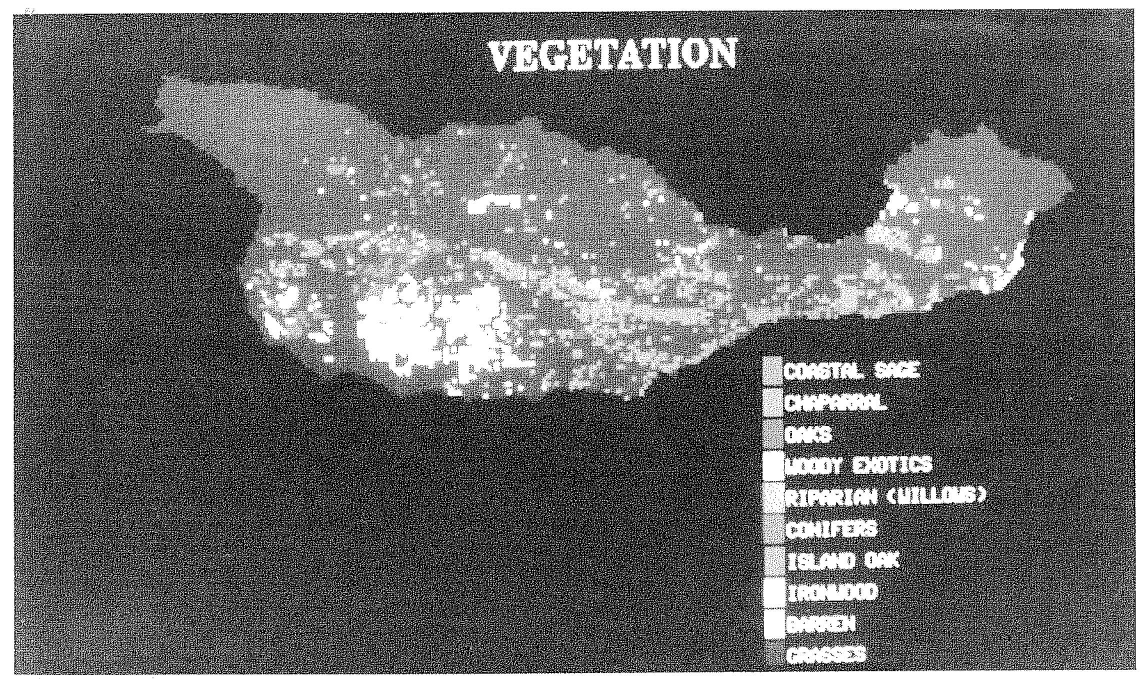

Figure 4. Vegetation layer of Santa Cruz Island GIS used for soil map construction. Note that this image shows only the primary vegetation classes which occupy $\geq 2/3$ of a cell, whereas the data enumerated in the tables includes cells mapped with a secondary class of oaks, chaparral, coastal sage, island oaks, ironwood, pines, riverine vegetation or barren land.

software program: 1) cross-tabulation statistics comparing the percentage of pixels of a class in one GIS data layer that occupied a particular class in a second GIS layer and 2) the number of pixels in common. This information was obtained in conjunction with a second ERDAS™ program that uses pairwise combinations of GIS layers as input to produce a new GIS file (*i.e.* a thematic map) containing class values that are encoded to show where the classes in the two original files coincide or overlap. Pairwise combinations with slope angle or aspect data at this spatial resolution contained little information related to the observed distribution of soils and were discarded. A file containing 11 vegetation classes was combined with a file containing ten geologic substrates to produce a map containing 110 preliminary map units, each representing a possible combination of vegetation and geologic substrate.

Only 60 of the 110 possible preliminary map units were used (Table 2). Some of the possible combinations of substrate and vegetation do not occur or do not occupy any significant area on Santa Cruz Island. Moreover, soils were sampled under only eight of the original 11 vegetation classes. Soils under coastal bluff, woody exotics and ironwood which each covered <2% of the island were grouped as "other" vegetation and not sampled. Island oak (*Quercus tomentella*) was not distinguished from other oaks during field soil sampling (Table 1).

To define final map units, the subgroup level classifications based on *Soil Taxonomy* (Soil Survey Staff 1975) of the soil profiles occurring in each preliminary unit were examined. Each soil map unit name was designated according to the relative proportions of soil subgroups represented by the sampled profiles (Table 2). Preliminary units with similar proportions were combined. For example, of the 27 profiles sampled under grass and coastal sage on Santa Cruz Island volcanics, over one half were Typic Haploxerolls, Lithic Haploxerolls, Pachic Haploxerolls or Vertic Haploxerolls, while about one-fifth were Lithic Xerorthents, one-seventh were Argixerolls, and one-tenth were Xerumbrepts or Xerochrepts. Slope angle or aspect information were incorporated in map units when they permitted further discrimination among subgroups within a unit. Many of the 60 preliminary units were combined in this process, resulting in 13 final map units (Table 2). To produce the final map, the image consisting of the geologic substrate layer overlaid with the vegetation layer was recoded to represent the 13 soil map units.

Results

Thirteen map units were defined for the island:

A. 55% Lithic Haploxerolls, Typic Haploxerolls, Pachic Haploxerolls, and Vertic Haploxerolls; 20% Lithic Xerorthents; 15% Calcic Argixerolls, Typic Argixerolls, and Vertic Argixerolls; 10% Typic Xerumbrepts, Lithic Xerochrepts and Typic Xerochrepts. Xerorthents and Xerochrepts are found mostly on steep backslopes, ridges and shoulders.

B. 65% Typic Haploxerolls and Lithic Haploxerolls; 20% Lithic Xerumbrepts; and 15% Typic Xerochrepts and Lithic Xerorthents.

C. 55% Lithic Haploxerolls, Typic Haploxerolls and Pachic Haploxerolls; 20% Typic Xerochrepts; 20% Lithic Xerorthents; 5% Typic Haploxeralfs.

D. 70% Lithic Xerorthents; 30% Lithic Haploxeralfs and Typic Haploxeralfs.

E. 40% Typic Xerochrepts and Lithic Xerochrepts; 40% Typic Xerorthents and Dystric Xerorthents; 20% Lithic Haploxerolls and Ultic Argixerolls.

F. 55% Typic Xerumbrepts, Lithic Xerumbrepts, and Entic Xerumbrepts; 40% Typic Haploxerolls, Lithic Haploxerolls, Pachic Haploxerolls and Ultic Haploxerolls; 5% Lithic Xerorthents. Haploxerolls are found principally on steep (>12°) slopes.

G. 60% Lithic Xerumbrepts, Typic Xerumbrepts, and Entic Xerumbrepts; 30%

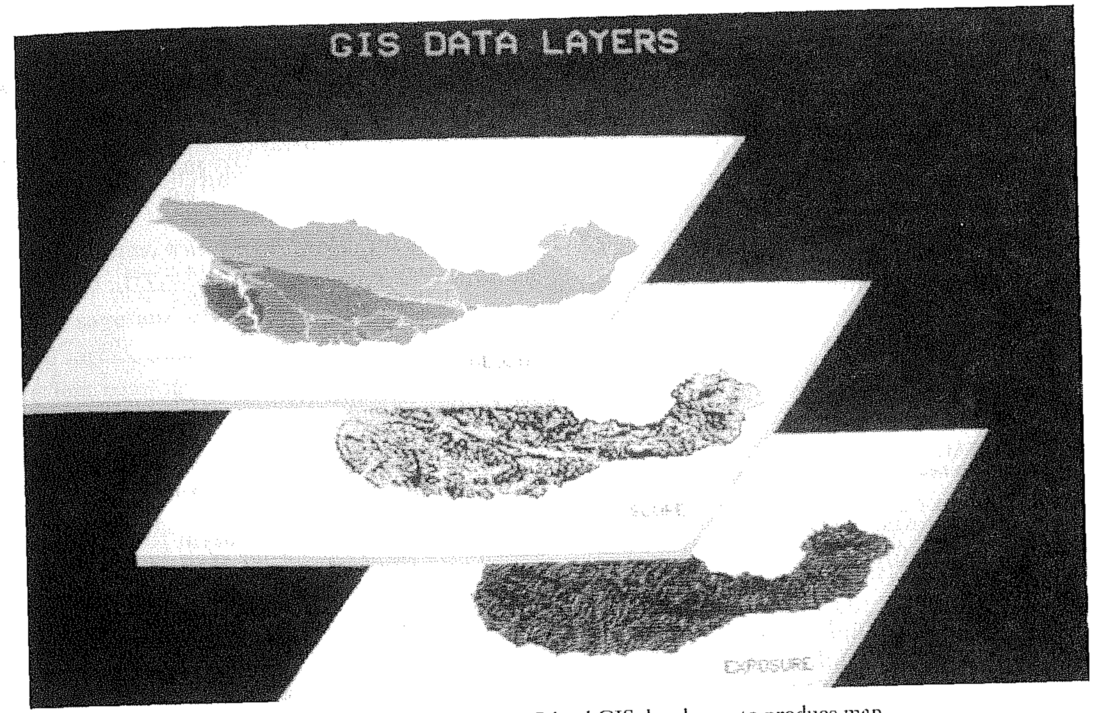

Figure 5. Overlay of Santa Cruz Island GIS data layers to produce map.

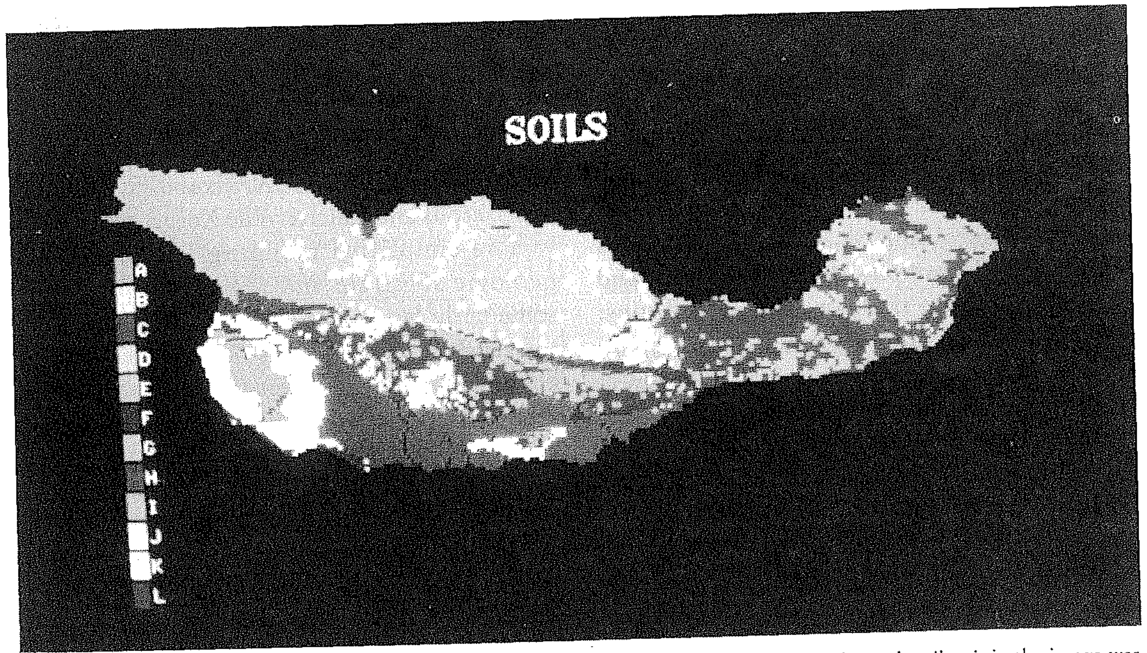

Figure 6. Computer-generated soils map of Santa Cruz Island. Note that the area covered by each soil unit in the image was produced by an overlay of the primary vegetation classes only, whereas the data enumerated in the tables includes cells mapped with a secondary class of oaks, chaparral, coastal sage, island oaks, ironwood, pines, riverine vegetation or barren land.

Table 3. Area covered by soil mapping units on Santa Cruz Island.

Unit	Great Groups	Profiles	km^2	% of island
A	Haploxerolls, Argixerolls, Xerorthents	27	91.1	36.6
B	Haploxerolls, Xerumbrepts, Xerochrepts, Xerorthents	15	20.7	8.3
C	Haploxerolls, Xerorthents, Xerochrepts	15	10.7	4.3
D	Xerorthents, Haploxeralfs	8	8.0	3.2
E	Xerochrepts, Xerorthents, Haploxerolls, Argixerolls	8	13.2	5.3
F	Xerumbrepts and Haploxerolls	13	26.9	10.8
G	Xerumbrepts and Xerorthents	12	14.4	5.8
H	Haploxerolls, Xerochrepts, Argixerolls, Xerorthents	14	28.4	11.4
I	Xerochrepts, Xerorthents, Argixerolls, Haploxerolls and Calcixerolls	11	5.7	2.3
J	Haploxerolls, Argixerolls, Calcixerolls	9	4.5	1.8
K	Xerochrepts and Xerorthents	6	7.7	3.1
L	Xerofluvents	7	17.7	7.1
M	Inceptisols with anthropic epipedon	1	0.0	0.0
	TOTAL	138	249.0	100.0

Lithic Xerorthents; 10% Ultic Argixerolls. Xerorthents are found principally on steep (>12°) slopes.

H. 30% Lithic Haploxerolls and Pachic Haploxerolls; 20% Pachic Argixerolls and Typic Argixerolls; 20% Calcixerollic Xerochrepts and Lithic Xerochrepts; 20% Lithic Xerorthents; 10% Typic Calcixerolls and Typic Xerumbrepts. Haploxerolls are found principally on lower backslopes and footslopes. Xerochrepts and Xerorthents are found principally on upper backslopes, ridges and shoulders.

I. 40% Typic Xerochrepts and Calcixerollic Xerochrepts; 30% Lithic Xerorthents and Typic Xerorthents; 20% Typic Argixerolls and Vertic Argixerolls; 20% Typic Haploxerolls and Pachic Calcixerolls. Argixerolls are found principally on shallow (<12°) slopes; Xerochrepts are found principally on steep (>12°) slopes.

J. 35% Typic Haploxerolls and Pachic Haploxerolls; 30% Pachic Argixerolls, Calcic Argixerolls and Typic Argixerolls; 20% Typic Xerochrepts and Lithic Xerorthents; 15% Vertic Calcixerolls.

K. 50% Typic Xerochrepts; 35% Lithic Xerorthents; 15% Lithic Haploxeralfs.

L. Xerofluvents, river wash and some recent depositional soils.

M. Inceptisols with anthropic epipedons.

Map units and their relation to preliminary combinations of geologic substrate and vegetation are shown in Table 2. Several map units (*i.e.*, F, G, H and I) are broken down according to hillslope angle or position.

The soil map is shown in Figure 6. The dominant soil taxa on the island at the subgroup level of *Soil Taxonomy* are Typic Haploxerolls, Lithic Haploxerolls, Lithic Xerorthents, Typic Xerumbrepts, Lithic Xerumbrepts and Typic Xerochrepts (Table 3). Smaller areas are occupied by Lithic Haploxeralfs, Typic Haploxeralfs, Vertic Haploxerolls, Pachic Haploxerolls, Vertic Argixerolls, Pachic Argixerolls, Vertic Calcixerolls and Calcixerollic Xerochrepts.

The simplified mapping rule based on geologic substrate and vegetation produced some fairly homogeneous groups of soil taxa at the subgroup level. Nearly 60% of the island is covered by the three largest mapped units, representing soils on volcanics and volcaniclastics under grasses and/or oaks and soils on the Monterey formation under grass. Soils on volcanic or volcaniclastic parent materials under grasses are predominantly Lithic Haploxerolls and Typic Haploxerolls with some Pachic Haploxerolls and various Argixerolls, notable for their thick, organic matter-rich surface horizons (mollic epipedons). Haploxerolls also predominate on volcanic parent materials under oaks and chaparral, and on Santa Cruz Island schist under grass and oaks. Thus units dominated by Haploxerolls and Argixerolls (A, B, C, H and J) cover over 60% of the island (Table 3). Soils on the Monterey formation are predominantly Xerumbrepts, with Haploxerolls on steep grassy slopes, and Xerorthents on steep slopes under oaks, sage and chaparral. Xerumbrepts have dark surface horizons (umbric epipedons) which are less base-saturated than mollic epipedons, and units dominated by these soils (F and G) cover about 17% of the island. Xerochrepts, which have less well-developed surface horizons (ochric epipedons) occur under coastal sage, chaparral and oaks on a variety of substrates. Units dominated by these soils (units E, I and K) cover over 10% of the island.

The remaining 1/8 of the island contains a wide range of soil subgroups that reflect the greater heterogeneity of vegetation and substrate in the south and southwest portions of the island. Several distinct soil subgroups occupy the Santa Cruz Island schist, Willows diorite, and Alamos plutonite. Soils on these Jurassic substrates (units C, D and E) include Pachic Haploxerolls in grassy depressions, Ultic Haploxerolls and Dystric Xerorthents on some eroded, deeply weathered sites, and Lithic Haploxeralfs and Typic Haploxeralfs under pines and sage. Soils on the Canada, Pozo and Rincon formations (units I and J) include Vertic Calcixerolls, Pachic Calcixerolls, Vertic Argixerolls, Pachic Argixerolls and Calcic Argixerolls on gentle slopes and flat areas, and Calcixerollic Xerochrepts and Lithic Xerorthents on barren areas or steep slopes under grasses. Xerofluvents or undifferentiated river wash (unit L) occur in stream valleys and occupy at most 7% of the island. No soils under woody exotics, such as *Eucalyptus* or *Acacia* spp., were described or classified. Midden soils (unit M) are characterized by an anthropic epipedon and occur as inclusions in most of the other units.

Discussion

Soils of Santa Cruz Island can be characterized by 13 broadly defined soil map units. Each of these units is a combination of soils (pedons) that classify into up to four soil great groups as defined in *Soil Taxonomy*. The soils map captures important general features of island soils: many have thick, dark surface A horizons and subsurface cambic or weakly developed argillic horizons. Much shallower soils, with little horizon development, occur on steep slopes, ridges, or shoulders on all geologic substrates.

High spatial variability of soils is the salient feature of the soil map. Soils identified as belonging to 11 subgroups of the USDA *Soil Taxonomy* (Soil Survey Staff 1975) occur in the large area of island volcanics under grass (37% of the island), with soils belonging to two or three subgroups typically occurring in a single 2.25 ha grid cell. The southwest corner of the island has the most heterogeneous soils (14 subgroups) and the greatest soil spatial variability, with four or more subgroups in a 150 x 150 m cell. The mosaic pattern, typified by many Lithic Xerorthents in close proximity to profiles in Pachic subgroups of Haploxerolls and Xerumbrepts, appears to be associated with soil erosion. Shallow, weakly developed soils also are found at all landscape positions, under all vegetation types, on the Jurassic Santa Cruz Island schist, Willows diorite and (to a lesser extent) on the Alamos plutonite. Although current erosion rates on these deeply weathered substrates are not high (Brumbaugh 1983), soils appear to have been truncated by an episode of severe sheet and gully erosion.

Combinations of vegetation and substrate proved to be useful in discriminating soils at the great group level of *Soil Taxonomy*, producing distinct, although heterogeneous, map units. However, soil taxa were not related systematically to slope angle or aspect at the grid scale. Two factors contribute to this result: 1) the spatial resolution of the gridded slope angle and aspect information is too coarse to accurately capture the relief which controls erosion and deposition on the island and 2) eroded, truncated soil profiles are irregularly and unpredictably located at all hillslope positions. Consequently, GIS vegetation and geologic substrate layers formed a useful basis for soil mapping, but slope angle and aspect information at the GIS grid scale (2.25 ha) could not be used to predict soils.

Several limitations to the soil map in its present form are apparent. A major weakness of the map is that the spatial resolution of the GIS is too coarse to capture the variability of some island features. Many cells contained two or more geologic substrates or vegetation classes as well as numerous slope angles and exposures. For example, riparian soils (unit L) were probably overestimated, because of the digitizing rule which designated an entire cell as riparian vegetation even when it covered only a small portion of the cell, and soils under pines, oaks, and woody exotics were similarly overestimated. Even truncated soil profiles occurring in expected hillslope positions such as ridges or backslopes could not be predicted using the gridded slope and aspect information. These mapping limitations are to be expected because the spatial resolution of these GIS data layers was less than that of the digitized features, especially topography.

A related and perhaps more serious limitation is that soil genesis is strongly influenced by vegetation removal and erosion, but the spatial variability of these processes, which probably vary within and between substrates, could not be characterized in the GIS. For example, some 150 x 150 m areas (single grid cells) described during field sampling in gullied areas in the southwest of the island contained soils classified in four distinct subgroups of the *Soil Taxonomy*. To capture the high soil spatial variability within single grid cell areas on a map with 2.25 ha resolution, each of the 13 soil map units was defined according to the expected proportions of various soil subgroups within cells belonging to that unit, rather than by attempting to draw boundaries between subgroups. While this probabilistic approach to soil map unit definition avoids some limitations that defined boundaries would create, it implies that there is no structure to the spatial pattern of soils in a given unit, which is misleading.

It is difficult to assess how serious these errors are compared to those from standard National Cooperative soil surveys, which do not include formal accuracy assessments (*e.g.* U.S. Department of Agriculture 1985a, b). On the one hand, the minimum mapping unit could be a single 2.25 ha cell, implying a spatial resolution as high or higher than standard National Cooperative surveys. On the other hand, the simplistic boundary definitions based on vegetation and substrate produce heterogeneous map units with low precision. Errors in the form of inclusions of soil subgroups not mentioned in a given unit are estimated to be 25% or less, even for the least thoroughly sampled units. This is considerably higher than the accuracy of SCS surveys, but in the absence of further sampling, it is at best only an estimate.

In addition to limiting accuracy, the gridded format limits the utility of the map for field research. Because no landscape features are visible at this grid scale, specific sites cannot be located. A polygon soils map could be produced using the same mapping rules and the original polygon maps of vegetation and substrate. This procedure would allow the designation of smaller, more irregularly shaped map units, while also showing landscape features. However, use of a polygon format in a GIS-based map may distort spatial resolution and bias the spatial distribution of errors, for example by creating false polygons (Burrough 1986).

A polygon map begs the question of whether the mapping rules, based simplistically on vegetation and substrate classes, are valid. Instead of classifying soils using a pre-existing system (Soil Survey Staff 1975), and defining map unit boundaries by overlaying two GIS layers representing simplified principles of soil genesis (Jenny 1984), a GIS has the potential to encode and apply much more sophisticated internal decision rules for soil classification, map unit definition, or generalization. Such internal rules might depart considerably from standard soil survey methods. An alternative basis for soil map units may be more appropriate to natural resources research on Santa Cruz Island, where conservation rather than agriculture is the objective. In addition, the simplistic rules used for map unit generalization could be improved by utilizing the chemical and physical data from the 138 classified soil profiles. This possibility is currently being explored using the GIS in combination with a multifactorial or hierarchical classification procedure (see Jones 1989; Michaelson *et al.* 1986) to test the relationships between soil chemical, physical and biological properties and soil-forming factors.

Despite its deficiencies, the map in its present form represents a considerable advance over previous knowledge of the nature and distribution of island soils, which have never been mapped. This map is one of the first known attempts to apply even simplistic rules to a spatial data base in a formalized context for soil map unit definition and generalization. A logical next step would be to compare the interpretive usefulness of this survey to the outcome of a standard soil survey conducted by an experienced soil scientist according to National Cooperative Soil Survey procedures. In the meantime, our results suggest that the dasymetric approach suggested for soil mapping by Fisher (1988) can be applied to produce categorical soil maps using a GIS. Clearly more elaborate mapping rules must be made explicit and alternative classification methods should be explored for some applications; this work is now in progress. Nevertheless an automated approach to mapping soils using GIS in large, remote areas appears to be a promising technique based on this example.

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Editor's Note: The photographs submitted to illustrate this paper could not be reproduced in color. Black and white reproduction of the maps resulted in considerable loss of detail. Color Xeroxes can be requested from the authors.

BOTANY

A. Terrestial

B. Marine