One Approach To The Development Of A Simple Geographic Information System For Management Of Natural Resource Areas

Greg G. Gaston

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Dr. C.L. Rosenfeld

ABSTRACT

This project explored one set of tools and procedures that appeared to have the potential to make the handling of the spatial data necessary for resource management more efficient and effective. This project used data from the Nature Conservancy's Lawrence Memorial Grassland Preserve and was designed to explore a low cost application of Geographic Information System technology.

Four pieces of software were used in this investigation

- Auto-Cad, a vector based drafting and design program.
- Surfer, a raster based three dimensional modeling program.
- Idrisi, a raster based image analysis/geographic analysis system.
- Auto-Tools, a raster to vector and vector to raster conversion program.

Data came from existing maps and small scale aerial photography. This data was to be augmented with data from recently acquired larger scale aerial photography. The data from the large scale photographs was to be electro-mechanically scanned and converted to digital information. This process proved to be impractical.

The need for more efficient and effective handling of spatial data can best be accomplished at this time by the utilization of one part of the experimental system, the computer assisted drafting and design program, Auto-Cad. Use of this system has provided for the development of an accurate, multi layer, base map of the Lawrence Memorial Grassland Preserve.

As the resolution and accuracy of the data base of the Lawrence Memorial Grassland Preserve is further defined and developed data can be placed in the Auto Cad system, providing both immediate benefits in enhanced information availability and storage of the best available data for eventual use in a more advanced system.

Chapter 1

Introduction

This project investigated the feasibility of developing a low-cost Geographic Information System which could be used as a prototype system for inventory and analysis of data concerning natural resource areas. It was directed towards the objective of organizing data from the Lawrence Memorial Grassland Preserve in a convenient form to assist land stewards of the Nature Conservancy in making management decisions.

To investigate the feasibility of developing such a Geographic Information System, a systematic procedure was followed, which included the following steps:

1) Construct of a computerized base map of the preserve, utilizing existing data sources;
2) Scan digitizing sample 70 mm color infrared air photos of the Lawrence Memorial Grassland Preserve acquired July 1988 and April 1989, utilizing the Eikonix scanning camera.
3) Convert the base map to a compatible raster format.
4) Combine the base map and digital image information into a prototype Geographic Information System.

As a result of this effort it was possible to evaluate this approach to system development in terms of its practicality, recommendations for further development, and insights into the technologies needed to make an image based system practical.

Problem

The Nature Conservancy carries out a complex resource management task with three major goals: (1) Identification of outstanding examples of natural heritage; (2) Protection of these areas through a variety of means, including rental agreement, easements, or purchase; and (3) Research and management activities designed to preserve and maintain the outstanding characteristics of the preserve (Frenkel,1988).

Many equate the term "natural" with the absence of human activity; thus it might seem strange that an organization dedicated to the preservation of natural areas should be vitally concerned with active management decisions. In fact, an understanding of the various factors that cause change to an environment, the monitoring of such change, and the need for an active management program are all part of the preservation of natural areas.

An example, not necessarily restricted to this site, would be the question: Is the burning of vegetation in an area desirable or necessary for the development or maintenance of its desired condition? If burning is needed, what frequency and intensity would be desirable to retain the characteristics for which an area was singled out originally?

In the case of the Lawrence Memorial Grassland Preserve these management tasks are complicated by the necessity of maintaining, and periodically extracting information from, a number of separate and incompatible data bases. It is apparent that a flexible, easily accessed, updatable information system would facilitate the decision making process and provide a useful management tool. This system should provide:

- Accurate locations and descriptions of important features
- High quality maps for field and research use
- Special information to aid decision the decision making process.

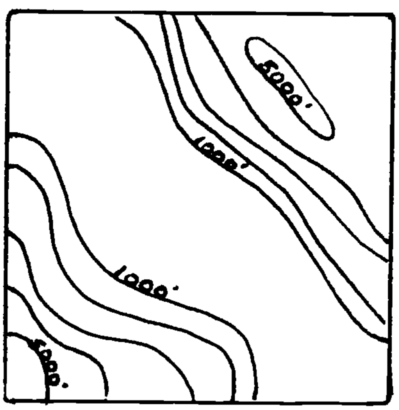
This project was undertaken at the request of The Nature Conservancy and investigated the considerations necessary for effective system design and the specific advantages and disadvantages of the system as they relate to The Nature Conservancy's goals.

The general term applied to a spatially oriented information system is a Geographic (or Geographical) Information System. Numerous approaches and Geographic Information Systems have been developed for resource management, in order to determine the best approach to solve this particular application it is necessary to ask several questions, the first of which is:

Just what is a "GIS" ?

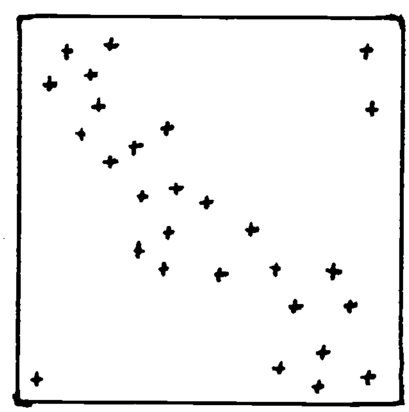
Since man first scratched in the dust to point out the location of game, the map has been the basic communicator of spatial information. Maps have changed and developed as survey and cartographic techniques have developed, but the basic nature (a set of lines drawn on a flat surface) of the map as THE spatial data base has not changed.

The scientific study of the universe and the earth provided levels of information that were specific to one investigation or use. These new data gave rise to the thematic map, a spatial reference for information that is not necessarily spatial in nature (Burrough,1989). This method of mapping allows a human interpreter to make evaluations of spatial relationships. For example, consider two maps:



The first is a topographic map constructed to show the surface of the earth as a set of lines connecting locations of equal elevation.

The second is a map identifying places of high economic development, these sites of economic development are tied to a reference grid and plotted as this map.



The human mind is capable of intuitively recognizing the connections between different sets of data, in this example slope/elevation and economic activity,(apparently flat land is more suitable for economic development). This process of recognition and analysis is carried out through simplification (filtering out the extraneous data) and classifying (developing relationships between like and unlike objects) (Kimerling,1988).

The explosion of information available and necessary for evaluation has made the digital computer developed in the 1960's an indispensable tool for storage, retrieval, and manipulation of data (James,1981:137).

The computer is capable of perfect memory and perfect recall and can perform simple repetitive tasks at a rapid rate. These characteristics make the computer an ideal aid to the human brain which, while possessing the ability to make intuitive connections, lacks perfect recall and quickly becomes fatigued by repetitive tasks (Burrough,1989).

The simplest computer aid to spatial information management consists of the CAD (Computer Assisted Design) programs. These are systems developed to execute and manipulate line drawings. Drawings (basic graphic communications, which include maps) can be stored and recalled, changed and reconfigured at will. These attributes transfer well to the display of spatial information (Berry,1989).

The Auto-Cad program is an example of a CAD program adapted to mapping. Points and lines are stored as a series of xy coordinates. Multiple levels of information can be contained as different "layers" which act as transparent overlays. A limited amount of attribute information can be attached to each entity (in recent releases color and elevation) (Raker,1988).

The ability of CAD systems to handle all the data that is associated with spatial data is limited, suggesting the need for further development of a data management system with an enhanced ability to handle the variety of information contained in spatial problems.

A spatial data base management system allows for the topology of a map entity (the list of characteristics associated with each point, line or area) to be attached to each entity (Kimerling,1988). This system can be likened to the attachment of a spread sheet of information to each point, allowing the sorting of information in the spread sheet and the identification of the resulting spatial distribution.

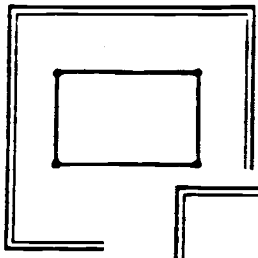
A true Geographic Information System is not so much a mapping system as it is a design to allow for the numerical analysis of spatial data and the production by the computer of new information developed by manipulating existing spatial data. This process mimics human intuition by substituting extensive iterations of the same calculations for insight (Berry,1989).

Two approaches have been taken to the problem of handling large amounts of spatial and associated non-spatial information. The vector format shares the line drawing nature of the CAD programs, storing spatial data as a series of points, lines and areas. These entities are given attribute data and the relationships between entities can be determined (Burrough,1989:25). The vector system of processing allows for the most precise and accurate location of objects (Kimerling,1989).

The calculations in a vector system are extremely involved and the data storage requirements for a complex area can be enormous. (See Figure 1)

The raster data structure (See Figure 2) is extremely simple, spatial phenomena are represented as an array (a tessellation) of identically sized and shaped grid cells (pixels) arranged in numbered rows (horizontal) and columns (vertical). This method is a computationally simple way of manipulating data; and while the data storage requirements can be high, complex topological relationships require much less computer time and power than a vectorized array of the same area (Burrough,1989:21).

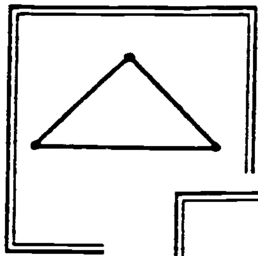
Logical and statistical operations can be carried out over rasterized images with simple algorithms, usually involving simple pixel counting operations, or Boolean logical operators. This allows for quick processing of complex analysis (Burrough,1989:20).



RECTANGLE

RECTANGLE

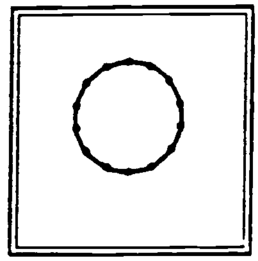
Segment#	Coordinates		Polygons
1	X,Y	X,Y	P1/BG
2	X,Y	X,Y	P1/BG
3	X,Y	X,Y	P1/BG
4	X,Y	X,Y	P1/BG



TRIANGLE

TRIANGLE

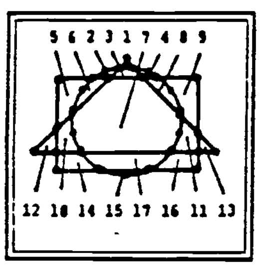
Segment#	Coordinates		Polygons
1	X,Y	X,Y	P1/BG
2	X,Y	X,Y	P1/BG
3	X,Y	X,Y	P1/BG



CIRCLE

CIRCLE

Segment#	Coordinates		Polygons
1	X,Y	X,Y	P1/BG
2	X,Y	X,Y	P1/BG
3	X,Y	X,Y	P1/BG
4	X,Y	X,Y	P1/BG
5	X,Y	X,Y	P1/BG
6	X,Y	X,Y	P1/BG
7	X,Y	X,Y	P1/BG
8	X,Y	X,Y	P1/BG
9	X,Y	X,Y	P1/BG
10	X,Y	X,Y	P1/BG
11	X,Y	X,Y	P1/BG
12	X,Y	X,Y	P1/BG
13	X,Y	X,Y	P1/BG
14	X,Y	X,Y	P1/BG



COMPOSITE

Polygon	Attribute
1	TRIANGLE
2	CIRCLE
3	T-C
4	CIRCLE
5	RECTANGLE
6	R-C
7	R-T-C
8	R-C
9	RECTANGLE
10	R-T
11	R-T
12	TRIANGLE
13	TRIANGLE
14	RECTANGLE
15	R-C
16	RECTANGLE
17	CIRCLE

COMPOSITE

Segment#	Coordinates		Polygons
1	X,Y	X,Y	P1/BG
2	X,Y	X,Y	P1/P3
	X,Y	X,Y	P1/P3
3	X,Y	X,Y	P1/BG
4	X,Y	X,Y	P2/BG
	X,Y	X,Y	P2/BG
5	X,Y	X,Y	P2/P3
6	X,Y	X,Y	P2/P6
7	X,Y	X,Y	P3/P4
8	X,Y	X,Y	P3/P7
9	X,Y	X,Y	P4/BG
	X,Y	X,Y	P4/BG
10	X,Y	X,Y	P4/P8
11	X,Y	X,Y	P5/BG
12	X,Y	X,Y	P5/P6
	X,Y	X,Y	P5/P6
	X,Y	X,Y	P5/P6
13	X,Y	X,Y	P5/P10
14	X,Y	X,Y	P5/BG
15	X,Y	X,Y	P6/P7
16	X,Y	X,Y	P7/P8
17	X,Y	X,Y	P7/P11
	X,Y	X,Y	P7/P11
	X,Y	X,Y	P7/P11
18	X,Y	X,Y	P7/P15
19	X,Y	X,Y	P7/P10
	X,Y	X,Y	P7/P10
	X,Y	X,Y	P7/P10

Segment#	Coordinates		Polygons
20	X,Y	X,Y	P8/P9
	X,Y	X,Y	P8/P9
	X,Y	X,Y	P8/P9
21	X,Y	X,Y	P9/BG
22	X,Y	X,Y	P9/BG
23	X,Y	X,Y	P9/P11
24	X,Y	X,Y	P10/P14
25	X,Y	X,Y	P10/P12
26	X,Y	X,Y	P11/P13
27	X,Y	X,Y	P11/P16
28	X,Y	X,Y	P12/BG
29	X,Y	X,Y	P12/BG
30	X,Y	X,Y	P13/BG
31	X,Y	X,Y	P13/BG
32	X,Y	X,Y	P14/P15
	X,Y	X,Y	P14/P15
33	X,Y	X,Y	P14/BG
34	X,Y	X,Y	P14/BG
35	X,Y	X,Y	P15/P16
	X,Y	X,Y	P15/P16
36	X,Y	X,Y	P15/P17
37	X,Y	X,Y	P16/BG
38	X,Y	X,Y	P16/BG
39	X,Y	X,Y	P17/BG
	X,Y	X,Y	P17/BG

Figure 1. An example of vector data. The coordinate data is at the right of each figure. The initial storage needs are small and the data structure relatively simple. When the three figures are overlaid the increase in complexity and storage is quite large (Berry,1989).

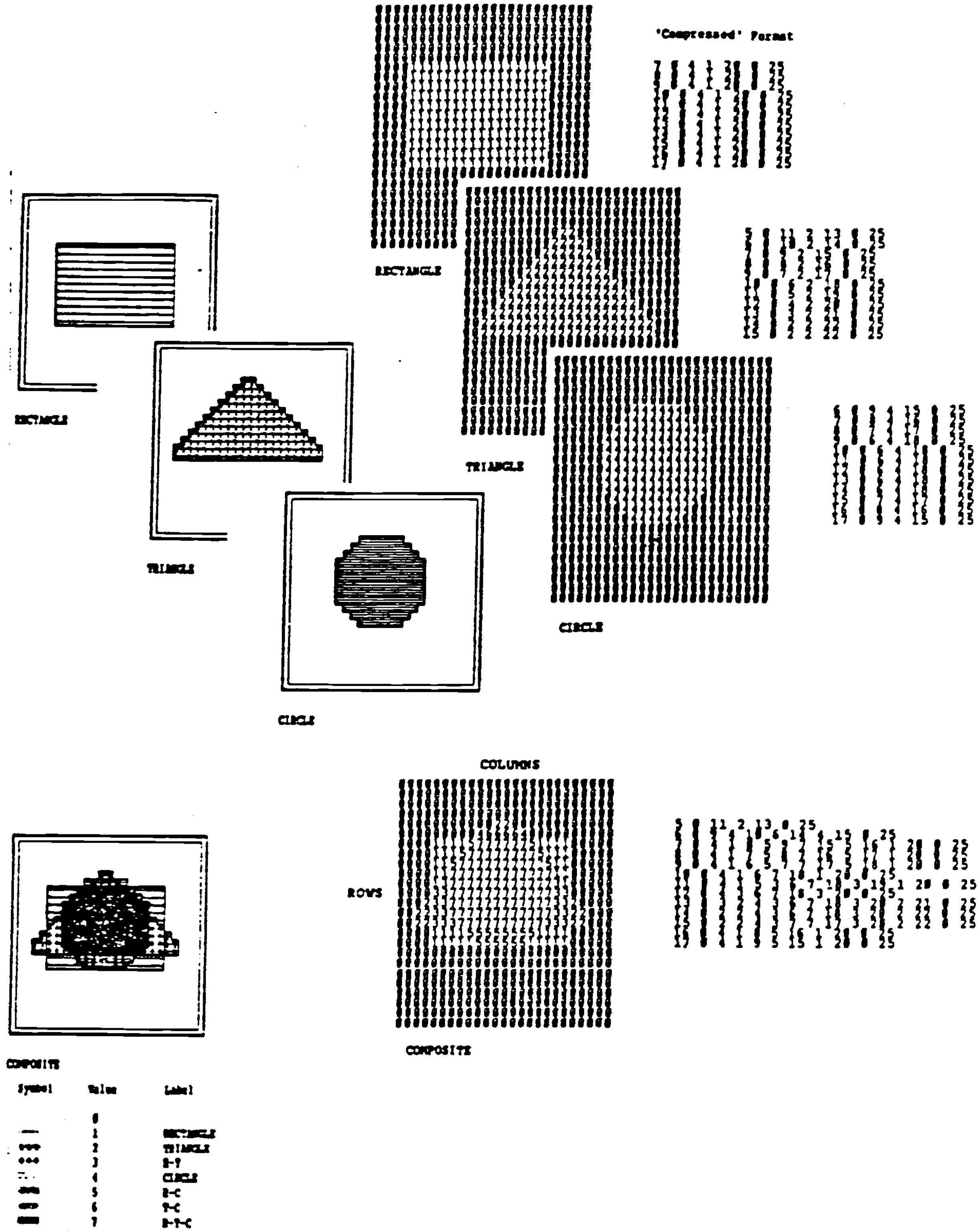


Figure 2. The raster data structure for the same three figures; the initial storage requirements are rather large because of the necessity of recording information for each pixel separately. Overlay operations and other analytical procedures are simplified and require less time and storage space (Berry,1989).

Most of the low cost GIS packages, PMAP (Professional Map Analysis Package)and IDRISI for example, are raster based programs that function well in a micro computer environment. The advantages and disadvantages of raster and vector methods have been summarized by Burrough as shown in Table 1.

Table 1

Raster and Vector Data Structures

Vector methods

Advantages
- Good representation of phenomenological data structure
- Compact data structure
- Topology can be completely described with network linkages
- Accurate graphics
- Retrieval, updating and generalization of graphics and attributes are possible

Disadvantages
- Complex data structures
- Combination of several vector polygon maps or polygon and raster maps through overlay creates difficulties
- Simulation is difficult because each unit has a different topological form
- Display and plotting can be expensive, particularly for high quality, colour and cross-hatching
- The technology is expensive, particularly for the more sophisticated software and hardware
- Spatial analysis and filtering within polygons are impossible

Raster methods

Advantages
- Simple data structures
- The overlay and combination of mapped data with remotely sensed data is easy
- Various kinds of spatial analysis are easy
- Simulation is easy because each spatial unit has the same size and shape
- The technology is cheap and is being energetically developed

Disadvantages
- Volumes of graphic data
- The use of large cells to reduce data volumes means that phenomenologically recognizable structures can be lost and there can be a serious loss of information
- Crude raster maps are considerably less beautiful than maps drawn with fine lines
- Network linkages are difficult to establish
- Projection transformation are time consuming unless special algorithms or hardware are used.

Source: Burrough, 1989

Both raster and vector data systems are completely acceptable alternatives for Geographic Information System development. A common approach is to combine both functions in a single package to take advantage of the strengths of both methods (Berry,1989). This investigation approached the problem by combining a vector based mapping program, AUTO-CAD with a raster based three dimensional modeling program, SURFER, and a raster based image processing/ GIS program IDRISI.

Whether raster, vector, or a combination of the two; any GIS system shares some common problems. It is necessary to turn the spatial data into a form useable by the computer. There are two common methods used for data entry and conversion - vector digitizing, and automated scanners (either "line following" vector scanners or raster scanners).

The digitizing tablet commonly contains a fine wire grid which records the xy location of points when an electromagnetic signal is triggered in the digitizing puck (or mouse). This type of input can be tedious to use but is very accurate and relatively rapid.

Line following scanners with high accuracy standards require large processing capacity and are not widely available (Burrough,1989:63). The raster scanner or image scanner converts areas of an image to digital values based on the amount of light reflected or transmitted. The processing algorithms used are similar to the Landsat scanning systems. Systems of this type are extremely useful for conversion of image information but are not usually used for conversion of mapped data. Both of these instruments represent an investment too large to be made by most organizations, requiring the aid of University research or outside contracting.

These are some of the overall system design considerations necessary to provide background for intelligent decision making

The Lawrence Memorial Grassland Preserve

This section provides background material concerning the preserve and its unique physical and biological characteristics. The Lawrence Memorial Grassland Preserve is a 380 acre site in Wasco County, Oregon (Figure 3). This site has been protected by the Nature Conservancy as it represents one of the best examples of "biscuit scablands", a feature that has been the subject of speculation and investigation for over 100 years. A fortunate set of circumstances, distance from water supplies, placement of fencing and land ownership has kept this area in a virtually undisturbed condition. This condition preserved several populations of rare plants from grazing pressure and reduced the disruption of the land surface by livestock trampling.

This area is a part of the Shaniko plateau which is composed of multiple layers of Columbia River flood basalts blanketed, by an irregular deposition of silty wind blown loess soils. The current climate is one of extremes, hot, dry, windy summers; alternating with cold dry windy winters. The average annual precipitation is 280 mm (Cox,1987). The annual temperature extremes do not often exceed 107 degrees F and -3 degrees F The soils are classified as a Condon-Bakeoven association. The Condon silt loam soils are formed from loess, volcanic ash and residuum weathered from basalt. These soils are concentrated in mounds separated by the Bakeoven very stony loam soils (Wasco County Soil Survey:120).

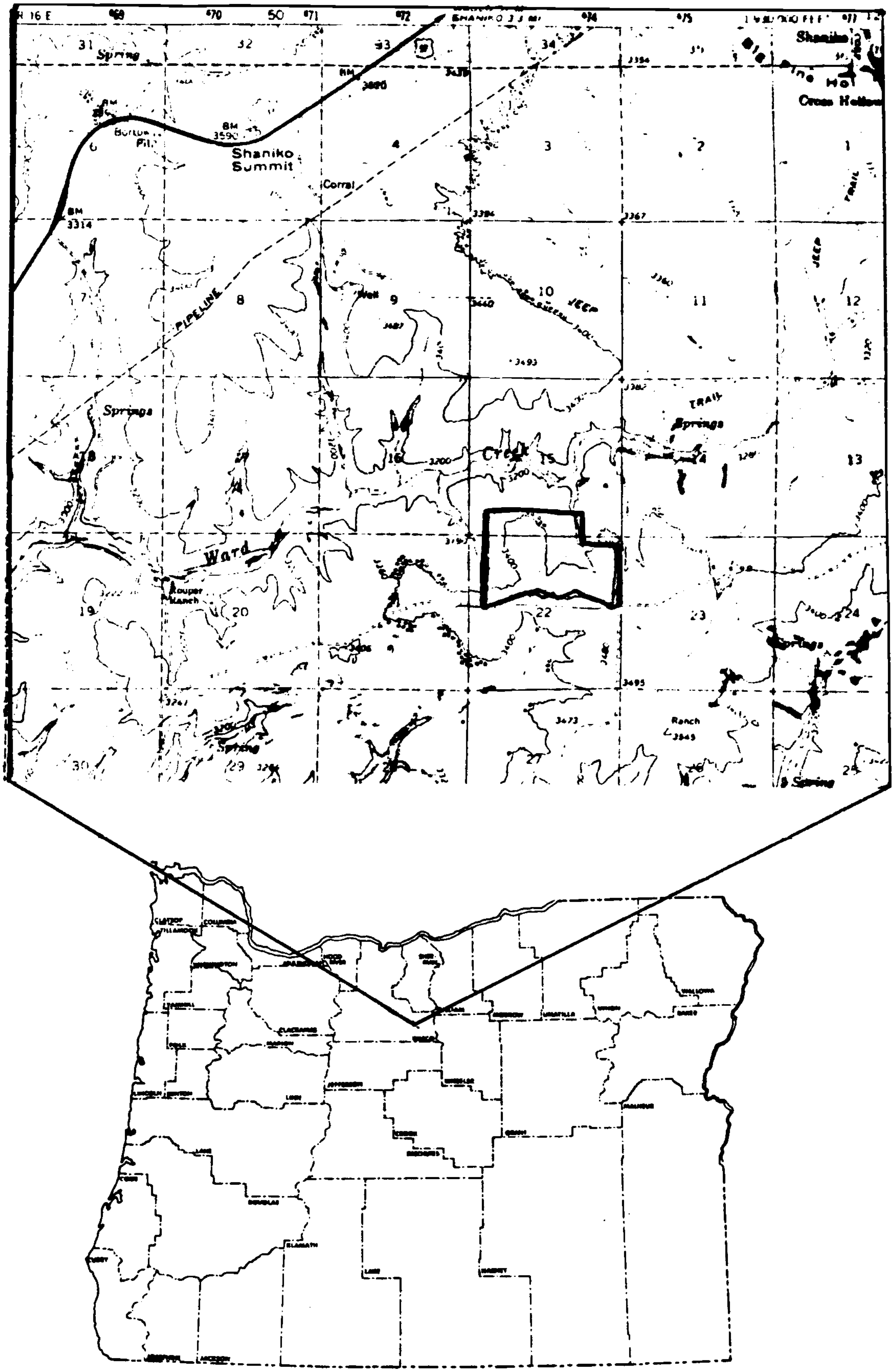

Shaniko Summit
PIPELINE
Corral
Springs
Ward
Creek
Rouper Ranch
Ranch
Cross Hollow
JEEP
TRAIL

Figure 3

The vegetation in the silty loam soils is dominated by Idaho Fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum); the stony Bakeoven soils are dominated by sagebrush (Artemisia spp.), Sandburg bluegrass (Poa sandbergii), biscuitroot (Lomatium spp.) and bitterroot (Lewisia rediviva) (Winward,1978).

A striking feature of this region is the presence of mounds of the loess soil separated by rings or nets of basalt fragments. These mounds commonly vary in size from one-half to 25 meters across and rise .5 to one meter above the surrounding rock nets. This mound topography known variously as "biscuit scablands" or "mima mounds" is especially striking from the air. Across this entire portion of the Columbia plateau stone nets separating soil mounds are common on nearly every ridge and cover a large percentage of the area. In Wasco County alone this mound topography covers approximately 35,000 acres (Wasco County Soil Survey:118).

The origin of these mounds has been the focus of speculation since at least the late 1800's (LeConte,1877). Numerous theories have been advanced to explain their formation. These can be grouped into two basic categories: (1) Biological hypothesis and (2) Geological/Geomorphological hypothesis.

Those supporters of a biological origin for the mound/intermound features maintain that they are a result of biological activity. The particular biological agent is cause for some speculation. The possible living originators range from fish constructing nests in an ancient glacial lake to the remains of aboriginal agricultural activity or burial mounds (Leconte,1877 and Dalquest,1942).

The consensus favorite for a biological originator for the mounds is the gopher; most specifically and recently the "geomyd pocket gopher (LeConte,1877, Dalquest,1942, and Cox,1987). These researchers maintain that large colonies of burrowing rodents common to this area at the end of the last glacial advance, began the process of mound construction, which has been modified by the physical processes of erosion and gelufluction (Cox,1987).

Considerable ink has been spilled by those researchers who cannot agree with any sort of biological origin, and maintain that the mound topography is only a result of physical processes.

Joseph LeConte maintained early on that the mounds were a result of "surface erosion under peculiar conditions " (LeConte,1877). Even more common is the assertion that these mounds are a result of periglacial processes. Ice wedging and sorting is a commonly observed phenomena in the tundra covered regions of the world where the formation of circular or hexagonal patterns in the soil and rocks, "patterned ground", is caused by ice wedging (Washburn,1956; Ritchie,1953). Supporters of the periglacial hypothesis maintain (with some variation concerning the specific processes) that in the period following the retreat of the glaciers, conditions were such that frost sorting caused the formation of the stone nets and differential erosion allowed the silty mounds to rise above the surrounding terrain (Malde,1964).

The debate over the origin of these mounds and stone nets is expected to continue and provide grist for the mills of numerous graduate research projects, such as those by Pyrch,1973; Nelson,1977; Tallyn,1980; and Johnson,1982.

Methodology

Chapter 2

Description and Analysis of Data

Construction of the base map:

A new base map of the Lawrence Memorial Grassland Preserve was constructed using data provided by the Nature Conservancy. These data consisted of:

- A PMT (photo mechanical transfer) of a single air photo identified as CCJ-IFF-221. This photo was acquired May 27, 1965

A 100 meter grid was overlaid on this PMT by Dr. Donald Lawrence in May of 1987. This grid was treated as the standard reference for all other materials.

- A PMT enlargement of the U.S.G.S. 15 min. topographic map sheet for Willowdale, Oregon (N4445-W12045).

The contour interval for this map was 40 feet. The 100 meter reference grid was also placed on this map by Dr. Lawrence.

- The vegetation locations were drawn from the vegetation map drawn by Alisa Gallant in 1980 which was based on Winward and Youtie's "Community Analysis of Higher Plants on the Lawrence Memorial Grassland Preserve" (Winward,1978:50-65). The reference grid on this map was different from the standard produced by Dr. Lawrence; adjustments were made in location of vegetation polygons where necessary during data entry.

- A diazo enlargement of air photo CCJ-IFF-221. This enlargement has been divided into two sections and the current research sites are located on these sheets.

The Auto-Cad drafting program recognizes only two points in referencing drawings; two identical points were selected on the grid of each source used and these data were digitized into an Auto-Cad drawing file. Each category of information (topographic contours, roads etc.) was assigned to a different layer allowing for the separation and manipulation of specific data. The vegetation polygons were digitized twice, once as a set of single vectors and again as a set of closed polygons. The reasons for this double digitization are discussed in the "integration and manipulation" of section of this paper. See Appendix 2, sample maps.

Aerial Photography and Image Scanning

Two sets of aerial photographs were available for this investigation; color infrared aerial photographs were acquired August 9, 1988 and May 14, 1989. Both sets of photographs were acquired from a camera nacelle located in the cargo door of a Cesssna 172, using a 70 mm Hasselblad camera fitted with a 50 mm metric lens and a Wratten #12 yellow filter. The film used was Kodak 2443, color infrared aerial film. The camera settings for both missions were 1/500 second at f-5.6.

The August mission was flown at 2000 feet above ground level, (approximately 5500 feet above mean sea level) , and covered the entire preserve in 15 frames. The May 14 photography was shot in a single pass at 3500 feet above ground level, (7000 feet MSL) and consists of 3 photos in a line along the South edge of the preserve, (along the road). A total of 8 frames were exposed at 5 second intervals, more than ample overlap reduced the effective coverage to 3 photos. These frames were captured en route to a different photo target and represent an unplanned opportunity for seasonal and scale comparisons. Appendix 1 contains prints of these photos.

The initial film product was a series of positive transparencies. (The originals of these transparencies are included as Appendix 5 in the bound copy of this paper in the Oregon State University Geoscience Department.) Hard copy prints were produced to aid analysis and a sample image was selected for initial processing.

In order to use information from the images in the computerized system it was necessary to convert the analog information on the transparency to a machine readable digital format. This operation was performed by using an Eikonix scanning camera and a high intensity light table which uses four 150 watt quartz halogen bulbs. The Eikonix scanner uses a linear array of charged couple devices (CCD's) to convert the quantity of light striking it into an electrical current, the current is assigned a digital value based on its strength, creating a machine readable image file. The array of CCD's is passed over the transparency, driven by an extremely fine step motor. The scanning camera used is capable of resolution up to 2048 pixels by 2048 pixels; this means each image or part of an image scanned can be divided into over 6 million individual picture elements. Display and processing limitations dictated the creation of images with a 512 by 512 pixel resolution.

In order to provide more data for use in processing the images, each sample image was scanned three times; each time using a different color separation filter. See appendix 4 for detailed spectral information concerning each filter used.

Initially the Eikonix scanner was supported by a Gould 32 MPX mini computer; using a converted form of the ELAS software. This converted software, ATLAS, was developed at the Geography department of Oregon State University. Numerous problems were experienced with this system, including total loss of data in a massive system failure. Data conversion and transfer, when undertaken at some future time, will be possible only by the development of an image processing capability using an 80-386 based micro computer.

Integration and Manipulation of Data

Two different approaches were used in the manipulation and integration of the data. The first concerned the vector to raster conversions necessary to make the map data amenable to manipulation in the Geographic Information System program. These procedures followed closely those developed by Riegleman (1989) and Gomez (1989).

Only two layers of information from the mapped data were deemed suitable for raster conversion; the vegetation communities mapped by Gallant in 1980, and the elevation data from the Willowdale topographic map. These transfers required the use of "Auto-Tools", a conversion package designed by Riegleman.

The creation of a digital elevation model (DEM) was accomplished in SURFER (a three dimensional display program) by use of interpolation algorithms that create a continuous surface of raster elevation values. The algorithm used for this conversion was the inverse square distance. The result of this process is seen on the frontispiece of this paper. This elevation grid allowed for the derivation of slope and aspect maps in IDRISI. (see Appendix 4)

The vegetation map was digitized twice; the first as single lines suitable for plotting in a map product; the second as individual closed polygons. The Auto-Cad program does not record the topology of entities that fall on either side of a line, it only recognizes polygons closed by a single line, thus the double digitization of each vegetation community. Even with the most careful attention to accuracy, this double recording of each line resulted in the creation of "slivers"; areas that fall between sections and do not belong to either polygon. This "slivering" is an inevitable part of the digitizing process (Honneycutt,1980).

The polygon map was transferred to IDRISI, again using Riegleman's Auto-Tools program (the CADTOIDR module).

These conversions and interpolations provided three data layers for use in the IDRISI Geographic Information System program; slope, aspect, and vegetation. An attempt was made to overlay the slope map with the vegetation map to provide an example of the possible overlay functions and produce a product that would demonstrate the function of a Geographic Information System for inclusion with this work. This proved to be unsuccessful when it was discovered that the data from the vegetation map needed to be changed to match the data from the SURFER file, (there need to be identical size and number of grid cells in both data sets). A conversion process exists but it is extremely involved and time intensive (Gomez,1989). An examination of the data indicated that the scale was too coarse and the output generated did not warrant further pursuit of this procedure at this time.

Image information that was to form the bulk of the data in this Geographic Information System was subject to several more problems than anticipated. It was not possible to simply scan and transfer the data from the image format to the Geographic Information System, and perform any analysis. Image data is not suitable for Geographic Information System use unless classified. This problem can be explained by remembering the "thinking" processes of a computer and a human mind; the human sees a string of points that appear to have identical characteristics, as a line, the computer "sees" only a series of individual points. The points of a line must be clearly classified as a line for the computer to recognize the linear relationship. This need for complete classification of the image data should have been anticipated, but was not.

The classification expected to be most suitable for the initial effort are the differences in spectral signatures between vegetation covered mound soils and the rocky intermound nets and denuded basalt slopes.

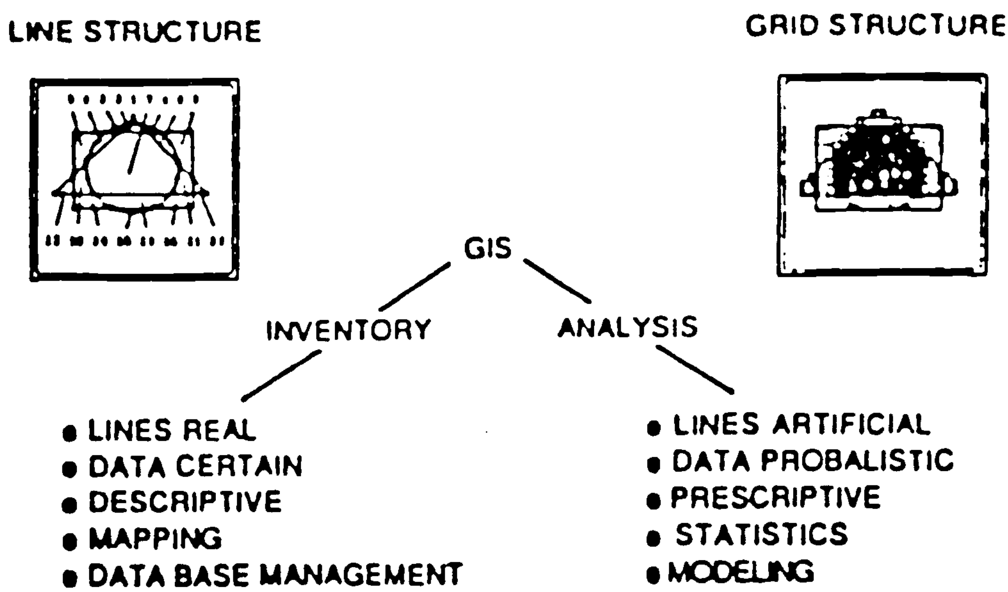
The classification process available in IDRISI relies on the selection of training sites, small areas that contain only the desired class. The pixel transmittance values are taken for the sample by using a "WINDOW", which entails simply removing the data for a small rectangle. This information is used to "RECLASS" the image, usually in a binary format. The binary map gives all the areas of the desired class an integer value and the balance of the map a zero value. This format makes the "overlay" functions very simple exercises of Boolean logic.

Findings

Chapter 4

Geographic Information Systems and appropriate technology:

The focus for this project was restricted to the investigation of various factors that affect the design of a Geographic Information System, and to the evaluation of one possible approach to such a system design. The process of system design is one of compromises and trade offs. One consideration is the selection of a data structure. Vector and raster formats both have advantages and drawbacks. This chart from Berry, 1989 offers some of the advantages of both formats.



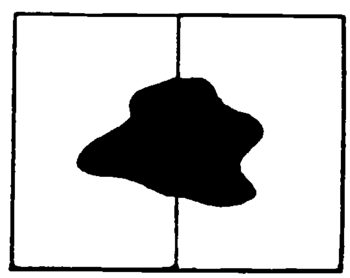
The primary advantages of the vector data structure are the "hard edges" available. A map can be constructed that precisely locates features in an area. These maps are visually acceptable and easy to interpret. A common consideration in cartography is the location of these hard edges when given a graduated boundary, the most common example offered for this is the linear separation of soil types; where should the line be drawn to separate the mixing soils of the boundary zone? In the case of the Lawrence Memorial Grassland Preserve many of these gradient edges do not exist. "... a person can often stand on a lithosol (soil type) with one foot in the margin of one association and the other in a different association!" (Daubenmier,1970:38).

Raster data structures are excellent for the development of "new" information. Information derived from the manipulation of existing data layers. This analysis of information is the primary criteria that separates a true Geographic Information System from other data base management and mapping programs; "The focus of a GIS is not maps... it is numerical analysis" (Berry,1989).

Raster data structures do not provide for the accurate locational information of geographic features; in fact it is easy to loose features altogether.

Consider this situation:

the feature in the center does not cover enough area to be represented in either grid cell, thus it does not appear in the data set.



The visual products generated by a raster system also suffer from human resistance to the display mode (see Appendix 4).

Aerial photography represents a great opportunity to develop useful information. Unfortunately several problems were experienced with the direct mechanical processing of the images. Computer problems were numerous with the Gould MPX 32, problems which culminated with the complete loss of the scanned images in the final system crash. The 386 PC represents a real opportunity to further develop and refine the image processing techniques using the scanned images from the Lawrence Memorial Grassland Preserve.

Additionally the low level images presented problems with vignetting, and aspect shadowing which hindered computer classification. An unsuccessful attempt was made at the start of this endeavor to survey a network of control points. A complete control network tied to the same 100 meter reference grid found on the other available data sources, using landmarks visible on the photography (junipers,for example) would be a great help in the optical transference of photo information to a base map using a zoom transfer scope. Using the zoom transfer scope would allow a trained human eye to evaluate and make judgments virtually unaffected by slight image differences. The information developed could be transferred to a base map, then transferred into the computer data using the digitizing tablet.

Conclusions/Recommendations

The needs of the Nature Conservancy for handling, processing and using spatial information are:

- accurate identification of objects and boundaries
- precise location of important features
- production of accurate and visually acceptable maps.

There is less demand for analytical capabilities than for accurate identification and recording of feature location. The raster programs tested in this investigation suffer from data resolution problems. Data resolution becomes increasingly more important as the scale of the area under study decreases. For example; the 50 meter by 50 meter grid cell of the surfer plot is unacceptably coarse when compared to the 380 acre extent of the entire preserve. An extremely fine resolution raster data base would reduce the problems associated with raster data structures (establishing accurate positions,etc.) but would not eliminate them.

At this time there appear to be two options; the first is to retain the analytical capabilities of a Geographic Information System using a vector based GIS. The vector based Geographic Information System that has garnered a large share of the market for such systems is ERSI'S (Environmental Systems Research Institute) Arc-Info. This program was developed to be supported by a mini computer such as a Vax, it has been modified to operate in a PC environment. The cost for PC Arc-Info software alone is between $12,000 and $17,000, depending on the number of analysis modules purchased. Perhaps as important as the cost of the program is the user interface problems associated with the PC version. Designed for large computer support, the PC version is extremely slow and awkward, as a result of this lack of speed and fundamental design flaws Arc-Info is considered by many users to have gone beyond non-user friendly to being "actively user hostile". The Arc-Info system is not considered a viable option due to the high cost and the long learning curve associated with the difficult program design.

The most efficient option available at this time is to abandon the analytical capabilities of the Geographic Information System and concentrate on the development of a fine resolution data base (micro-topography, locations of specific groups of endangered plants etc.) in a format that will provide immediate benefit. The establishment of this data base will facilitate the installation of a second generation Geographic Information System, and allow for immediate use as map products to aid the data gathering process.

Auto-Cad is used by over 70% of the computer assisted drafting market; it is an extremely user friendly program (maps have been made by students with only 5 minute of instruction); and a copy of the software can be obtained for approximately $3000. This project demonstrated the versatility of the Auto-Cad program for mapping and for data transfer. In spite of the slivering problems encountered in the transfer of polygons, the Auto-Cad DXF file can be used as input by numerous other Geographic Information System programs. According to Bob Wright formerly with the Bureau of Land

Management, now with InfoTech, the DXF format is rapidly becoming the standard format for transfer of spatial information.

The installation of an automated mapping system will meet the current needs of the Nature Conservancy and provide the opportunity to build on the data base additional information that will make the future implementation of a Geographic Information System truly useful.

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