Using Aerial Photography and Geographic Information Systems to Develop Databases for Pesticide Evaluations

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ABSTRACT: An example of the construction of a spatial and attribute database using aerial photography and GIS is described. Two vegetative layers on two large experimental plots were interpreted on the aerial photographs and digitized. A theme of trap locations was generated and linked to the results of 16 trapping days spanning periods before and after the application of a pesticide. The GIS was used to calculate values which will be used in a later study to model the effects of the pesticide on the small-mammal community. Both aerial photography and GIS show promise for improving the efficiency with which data can be gathered and processed for pesticide evaluations.

INTRODUCTION AND BACKGROUND

ONE OF THE IMPORTANT TASKS of the U.S. Environmental Protection Agency and other environmental agencies is to evaluate the effect of pesticides on non-targeted floral and faunal populations in the treated areas. The analytic techniques needed to perform these assessments are often complex, with intensive and extensive information requirements, which makes the evaluation process slow and expensive. The technologies of remote sensing and geographic information systems offer promise for streamlining this evaluation process. There has been ample precedent in the literature for using these new technologies to monitor and evaluate wildlife populations (Agee and Stitt, 1989; Donovan *et al.*, 1987; Heinen and Lyon, 1989; Johnson, 1990; Stutheit, 1989).

A project was initiated to examine the use of aerial photography and GIS for developing spatial databases which could be used in the pesticide evaluation process. In an earlier study of the pesticide methamatiphos, which provided the basis for this project, four treatment and two control plots were established in northeastern Colorado. The pesticide was applied to each of the four treatment plots, with two plots receiving a single application, and two a second application. The pesticide was targeted at insect populations, but the interest was on the effect of the pesticide on the remaining small-mammal populations which prey on the insects. A small-mammal trap grid was established on each plot, and the results of four trap periods of four days each were recorded. One trap period took place prior to the application of the pesticide, and three following the application over a specified time interval. To analyze this data set, a way to map the vegetation cover efficiently, and a way to correlate this vegetation information with the trapping results, was needed.

The power of a GIS resides in its ability to associate locations and characteristics, and its ability to cross-reference different types of spatial information. We needed both of these abilities in this endeavor. Our first need was to quantitatively characterize the vegetation in the vicinity of each trap by methods of neighborhood analysis. Because different faunal species travel different distances for food, water, and shelter (varying home range sizes), and these distances were largely unknown in these areas, it was necessary to characterize the vegetation within varying neighborhood sizes to help modelers determine the behavior of the species encountered. Clearly, this required that the analyses be easily repeated. Further, because trap locations and vegetation information were stored as separate themes, all these analyses would require Boolean combinations of some sort.

The objective of this paper is to describe how aerial photography and GIS were used to develop data sets for use in assessing the effect of a pesticide on a small-mammal population. This situation is similar to more traditional uses of GIS in that it is a spatially oriented problem, with all the requirements and limitations that implies. However, it is somewhat different from previous GIS applications because the data set was specifically designed and developed for analysis only. There is not otherwise any need to map experimental plots, except as the mapping applies to the spatial analyses performed. We emphasize that the spatial data sets developed in this study were constructed with different objectives in mind than, say, a subdivision or a forest stand database.

METHODS

PLOT DESCRIPTION AND PHOTOINTERPRETATION

Six experimental plots were established in the Colorado Plains Experimental Range in northeastern Colorado. Each plot was 225 metres square, or 5.06 hectares (12.5 acres). This area is a native shortgrass prairie, consisting predominantly of buffalo grass (Buchloe dactyloides), blue grama (Boutela gracilis), several midgrasses, and similar species (Stevens, 1989). Taller shrubs or small trees were also present on the plots in highly variable amounts. The topography was flat to gently rolling, and the elevation was approximately 1500 metres. Soils are shallow, sandy loams, and the rainfall was around 5 centimetres per year.

The four corners of each plot were targeted for precise aerial identification. Because of budgetary and time restrictions, two of the six plots were selected for examination in this study. This selection was based on aerial photo coverage and overall photo quality. Aerial photography was acquired of each plot just following plot establishment using a 9-inch camera carrying normal color film during a period of full-leaf cover. Positives were enlarged approximately 3 times and printed at a scale of about 1:700. Print contrast was reduced by the enlarging and printing processes, and scratches and marks on the originals marred the

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prints. Despite these defects, these photos were used in this project. The very large scale was necessary for the proposed photointerpretation and mapping objectives. Because these photographs were acquired during time periods spanned by the trapping sessions, there was no time lag between field efforts and the subsequent photointerpreted information. Further, the goal of the interpretation process was relatively simple – the location and delineation of shrubs – which should be accurate and consistent on these slightly degraded images.

The enlarged print for each of two plots was monoscopically interpreted using a 5× monocular magnifier. Because stereo coverage was not available, monoscopic interpretation methods were utilized. A clear mylar overlay was attached to each print, and all interpreted results were noted on these overlays. The intent was to map the location of individual shrubby or woody crowns, and the boundaries of each crown where possible. Although the grass species comprise the majority of the ground cover, it was the woody shrubs which are thought to provide shelter for most activities of the small-mammals. Thus, their location and extent are of primary importance when describing habitat quality.

The resolution of the photographs placed some limitations on the photointerpretation because some crowns were too small to delineate as polygons. These small crowns (generally less than about 0.50 mm across at print scale, depending on the shape) were coded as points, whereas larger crown boundaries were actually delineated as polygons. On Plot 1, 6498 "point" crowns and 2715 "polygon" crowns were delineated on the acetate. On Plot 2, 10122 point crowns and 2943 polygon crowns were identified and located on the acetate overlay.

DATABASE DEVELOPMENT PROCEDURES

The next step in the project was to create the digital spatial databases for each plot. The first type of spatial database contained the vegetation information interpreted from the aerial photographs, and the second was the trap location database.

Each acetate overlay was fixed to a 36- by 48-inch digitizing table. No surveying of the plots had been performed, and none could be afforded at this time. Further, the plots were in a very remote area lacking features suitable for the establishment of control. Thus, we decided to use the plot corners themselves as the control network. They were visible on the photographs (and located on the mylar), and the spacing on the ground was known. Clearly, this is somewhat different from more typical spatial databases. The exact position of the plots on the Earth's surface was not important at this stage, because only the relative positions of objects within the plot would be needed for modeling purposes.

Each plot corner was digitized in table inches using ARC/Info software, and later converted to a ground-based metric system using the TRANSFORM command. Target values for the transformation were easily determined for a square plot with corners 225 metres apart. A "POINT" file was created for each plot by digitizing the location of all "point" crowns as indicated on the acetate overlay. Each plot also had a "POLYGON" file containing the digitized boundaries of all crown "polygons" identified on the acetate overlay. Thus, four vegetation files were created, a point and polygon file for each of the two plots (Figure 1). Crown and point files were separately maintained throughout the study; however, their information was combined when needed using various Boolean operators.

A second digital spatial database was created for each plot, because an integral part of the evaluation process was the trapping pattern of animals over a period of time preceding and following the application of the pesticide. The spatial location of the traps was considered to be an important factor because trapping results depend upon the habitat quality at the location of the trap itself. The traps themselves were not visible on the photographs, nor was any other specific measured information available concerning the trap locations. The original experimental plans called for establishing traps at a 15-metre spacing across the plot, and field crews indicated that they painstakingly followed this scheme in the field. We were thus safe in assuming that this spacing plan was followed and therefore established traps on a 15-metre grid beginning at one plot corner using the ARC/Info GENERATE command. Trap locations were generated rather than digitized because it was felt that a manual location and digitization procedure offered more opportunities for error without producing any benefit over the automated procedure. Upon completion, each plot contained 256 traps.

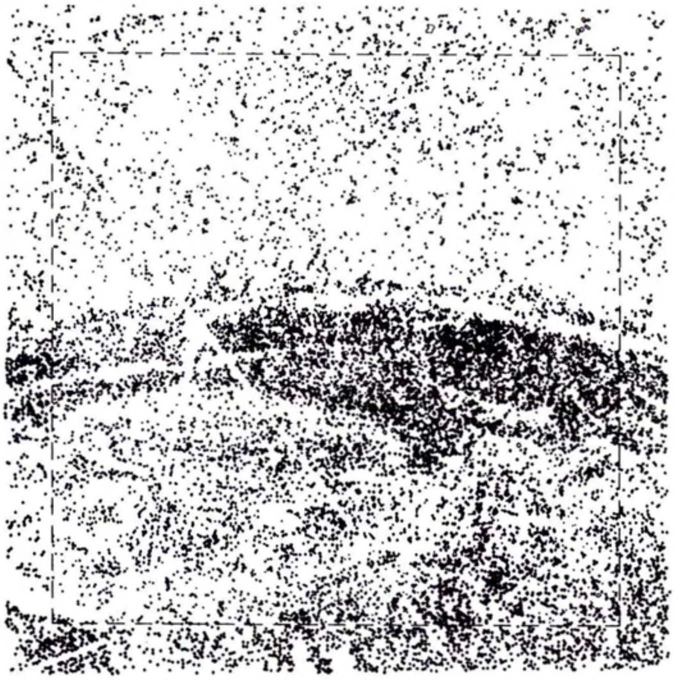

FIG. 1. Digitized version of the point and polygon crowns for Plot 2, with the boundaries for the plot indicated.

In summary, each of the two experimental plots had three spatial data themes associated with it: (1) a layer of digitized boundary locations for larger crowns, (2) a layer of point locations for crowns too small to have their crown delineated, and (3) a layer of generated trap locations.

The next phase of the study was to attach appropriate attributes to each layer. A critical component of any evaluation of small-mammal populations is the results of live trapping sessions, where the population size, composition, and condition can be assessed. Four trapping periods of four days each were conducted. For each successful trapping event, trap period and session (day), trap number, species of animal trapped, eartag number of the trapped animal, and several physiological descriptors were recorded. Traps which did not catch an animal during a trapping session had no values recorded. These observations amounted to an attribute database for the traps.

The power that GIS uniquely brought to this effort was the ability to link these trap attributes with the trap locations and with the vegetation information interpreted from the aerial photography. Trapping result files were imported into INFO from ASCII format. Each file consisted of the information from a single trapping period, i.e., one sequence of four daily trapping sessions (Table 1). Separate attribute files for each trap period for each plot were created because most analyses would be performed on individual trap periods. However, results could be combined across periods by using the relational capabilities of

INFO (or DBASE on pcARC). Because the trapping results were the trap attributes of interest, and we wanted separate databases for the four trap periods, it was necessary to make four copies of the trap location spatial database for each plot, one for each of the attribute data sets. Once these copies had been made, the JOINITEM command was used to permanently link a trap location layer to an appropriate set of trapping results, and the process was repeated until all trap periods were spatially referenced.

The databases were now complete. The data base for each of the two plots consisted of six themes of information. Themes 1 and 2 were the vegetation location information interpreted from the aerial photographs. The linked attributes for these two layers were the standard values computed by ARC/Info, namely, the area and perimeter of the polygon crowns, and the area and perimeter of the point crowns. Themes 3 to 6 were the four trap location databases, one each for the four trapping periods. The linked attributes for these layers were the trapping results previously described. Note again that it is beyond the scope of this paper to present the results of the mammal evaluations, although some uses of the GIS in this regard will be briefly described.

SPATIAL ANALYSES

The databases were created for purposes of spatial analysis. Although there was no "mapping" intent in a display sense, we will later describe display products which we believe may helpful to the modelers. We discuss in this section how the databases were used to calculate values that could be used in an assessment of a faunal population.

Within ARC/Info, the BUFFER command was used to generate circular proximity zones around each trap location with radii 1 metre, 2 metres, 5 metres, and 7.5 metres. Each zone size was maintained as a separate polygon theme in the corporate database. Each zone size theme was then combined with the point and polygon vegetation themes using the UNION command. This produced new themes which contained all point crowns within the critical distance, and all crowns or crown portions within the specified zone size. Because there were two plots and four zone sizes, this effort was made more efficient through the use of macros developed in the AML facility.

Several numerical descriptors were calculated for each trap using functions available within ARC/Info. First, the total crown area within the specified distances was computed by simply summing the crown areas (as automatically calculated by ARC/Info) in the overlaid files. In order to estimate total crown coverage, we needed to account for the crown area occupied by point crowns. These crowns were too small to resolve on the photography, but they occupy finite area on the ground.

We assumed that the area of individual point crowns was equal to one-half of the average area of the 150 smallest polygon crowns (separately done for each plot), then multiplied this value by the number of point crowns to estimate total point crown area for each of the two plots. By adding point and polygon crown area, we estimate total woody crown cover within different distances of the trap location. Within each proximity zone, the total number of interpreted point and polygon crowns was tallied and added to the database. This was considered to be a measure of the total number of stems within specified distances of each trap. The distance from each trap location to the nearest point crown, and the distance from each trap to the nearest crown boundary arc, were computed using the NEAR command within ARC/Info. Although the modelers may identify other values to be computed using the databases we developed, our plan was complete (Table 2). Note that these calculated values could be linked to the trap history results previously discussed using the relational capabilities of INFO or DBASE. The pros and cons of this effort will be discussed in a later section.

TABLE 1. EXAMPLE OF THE TRAP HISTORY DATABASE FOR TRAPS 12-33 IN PLOT 2 FOR DAYS 1 AND 2 OF THE PRE-TREATMENT TRAPPING PERIOD.

	DAY 1					DAY 2				
Trap	Tag #	Species[1]	Sex	Age[2]	Weight (grams)	Tag #	Species	Sex	Age	Weight
12	1,306	PEMA	M	1	23.000	0			0	0.0000
13	0			0	0.0000	0			0	0.0000
14	0			0	0.0000	0			0	0.0000
15	1,304	PEMA	F	3	15.0000	0			0	0.0000
16	1,303	PEMA	M	1	16.0000	0			0	0.0000
17	0			0	0.0000	0			0	0.0000
18	0			0	0.0000	1,318	REMO	F	1	12.0000
19	0			0	0.0000	0			0	0.0000
20	0			0	0.0000	0			0	0.0000
21	0			0	0.0000	0			0	0.0000
22	0			0	0.0000	0			0	0.0000
23	0			0	0.0000	0			0	0.0000
24	0			0	0.0000	0			0	0.0000
25	0			0	0.0000	0			0	0.0000
26	0			0	0.0000	0			0	0.0000
27	0			0	0.0000	0			0	0.0000
28	0			0	0.0000	0			0	0.0000
29	0			0	0.0000	0			0	0.0000
30	0			0	0.0000	0			0	0.0000
31	0			0	0.0000	0			0	0.0000
32	0			0	0.0000	0			0	0.0000
33	1,307	PEMA	F	3	13.0000	1,319	PEHI	M	1	50.0000

[1] PEMA - Peromyscus maniculatus; REMO - Reithrodontomys montanus; PEHI - Perognathus hispidus

[2] 1 = Juvenile; 2 - Subadult; 3 - Adult

As we progressed through the database development process, we began to see other GIS "products" that might be useful to the modeling process. These additional items were display products created by manipulating the trap history databases, or by merging the various spatial themes and the trap histories. These images of the data are important because in a complex modeling situation a greater understanding of the relationships between variables may be discerned with pictures than with raw numbers or statistics.

The first type of display product consisted of a trap location map, with the various traps labeled with text or different symbols according to important attributes in the trap history database, such as species trapped, or number of animals trapped over the period. This gave a strong indication of the spatial distribution of the trap results. The second type of display was a composite map of the two vegetation layers (point and polygon) and the trap locations labeled by attributes which helped modelers correlate trap results with vegetative composition. Finally, a third display was a three-dimensional view of the percent vegetative cover of the two plots, with the trap results draped over this surface. This was a capability unique to GIS, and our procedure requires further explanation.

We took a simplistic approach to the creation of the three-dimensional crown cover surface because the surface would be used only for viewing, not for calculating other values as is often done with topographic surfaces. Our approach was to use crown closure percentages computed from circular 7.5-m proximity zones and assume that they were the cell value for square 15-m cells centered on each trap location. This became a simple raster data set suitable for creating three-dimensional surface views.

We decided to use the IDRISI package for these views for two reasons: (1) IDRISI uses a file structure that could be easily created, and (2) IDRISI was an inexpensive and widely available package that was more likely to be obtained off-site if local

TABLE 2. EXAMPLES OF THE VALUES CALCULATED WITHIN THE GIS FOR TRAPS 12-33 IN PLOT 2.

	Number and Area of Crowns within the Specified Distance of Each Trip									
	1.0 Metre Radius		2.0 Metres Radiius		5.0 Metres Radius		7.5 Metres Radius		Metres to Nearest Point Crown	Metres to Nearest Polygon Crown
Trap	Num	Area (M^2)	Num	Area (M^2)	Num	Area (M^2)	Num	Area (M^2)		
12	0	0.0000	0	0.0000	7	0.7466	14	1.7270	3.4	6.1
13	0	0.0000	0	0.0000	2	0.0517	16	3.1405	3.5	4.4
14	1	0.1672	2	0.3345	6	0.7207	24	3.7365	0.9	3.2
15	0	0.0000	1	0.1672	4	0.6690	17	2.5636	1.9	4.7
16	0	0.0000	1	0.4430	5	1.1120	17	3.3845	3.7	1.0
17	1	0.0259	4	0.1866	14	1.7176	34	4.6777	0.8	1.3
18	1	0.0259	3	0.3119	12	0.5447	24	1.3024	0.5	1.1
19	0	0.0000	1	0.0259	7	0.1811	23	0.7874	1.6	7.1
20	1	0.2150	2	0.2439	10	0.4508	31	1.1492	1.3	2.4
21	0	0.0000	3	0.0776	22	0.5691	41	1.3130	1.5	2.9
22	2	0.3130	2	0.7600	10	0.9670	22	3.6429	2.2	0.3
23	2	0.1610	4	1.2179	20	1.6318	46	7.6393	1.5	0.6
24	1	0.1860	2	0.2119	15	0.5482	47	4.7903	1.9	0.2
25	2	0.0869	5	0.2107	24	0.7022	45	3.2355	0.5	0.0
26	0	0.0000	0	0.0000	1	0.0259	8	0.6336	2.2	4.1
27	0	0.0000	1	0.4260	5	0.5295	9	0.9061	2.3	1.3
28	0	0.0000	1	0.5280	7	0.6832	23	2.1682	2.1	1.1
29	2	0.1930	3	0.6380	8	0.7673	26	1.9756	3.9	0.4
30	0	0.0000	0	0.0000	2	0.0517	6	0.5345	3.6	5.5
31	0	0.0000	1	0.0190	3	0.0707	13	2.1992	2.8	1.9
32	0	0.0000	1	0.0610	4	0.4214	15	4.4901	3.4	1.8
33	0	0.0000	1	0.0780	9	1.1332	21	2.9720	2.7	1.8

personnel want to view the results. We found the initial results unsatisfactory because of the large cell size. There was little variation in the surface, and it was very blocky in appearance.

We recreated the crown closure surface at a 5-m resolution by first creating a 5-metre grid using the GENERATE command of ARC/Info, and using the BUFFER command to develop 2.5-metre radius proximity zones. We then overlaid this grid over the point and polygon crown themes, and computed the crown cover percentage in the proximity zone as described above. This raster file was imported into IDRISI and perspective plots were generated. The views generated from the 5-metre cell data were considered to be acceptable and helpful by the modelers. Various trap history files were also linked to the IDRISI images through QUATTRO and draped over the crown cover surface. An example is presented in Plate 1.

DISCUSSION

We fulfilled the principal objective of describing how aerial photography and GIS were used to construct databases designed for use in evaluating a small-mammal population following the application of a pesticide. It is relevant and important to discuss what we learned about the use of GIS and aerial photography in this context for the benefit of those who perform similar tasks in the future.

Several problems or difficulties were encountered during the course of the project. These accrue from imprecision in the spatial data sets, which creates imprecision in the values computed with it in order to assess the small-mammal population. Remember, it is the small mammal assessment that is the goal, not the maps or the attributes. In this study, database quality depended upon the characteristics of the aerial photographs, the skill and effort of the photointerpreters, the digitizing process, and the algorithms used to process the raw data.

The first potential source of spatial inaccuracies was associated with the aerial photography and photointerpretation. The aerial photography used in this project was of relatively poor quality. The original positives were scratched, and appeared to be slightly overexposed. When enlarged and printed, these problems were exacerbated. Thus, although the objective of the interpretation was the simple identification of shrubby or woody vegetation, there were undoubtedly some errors made by the interpreters. It is well known that "real" crowns are often missed by photointerpreters, and that "false" crowns are identified and mapped (Needham and Smith, 1987). Although it was likely that this problem was minimal in this project, we always urge all who pursue similar aims to use the very best quality photographs available. Photointerpretation accuracy can present significant problems as mapping objectives become more complex.

Besides image quality, image geometry could have created problems at these large scales in some situations. Because the mapping was performed monoscopically, image displacement could have been a significant degrading factor on the planimetric accuracy of the spatial data. However, the topography was generally flat, so even at these low flying altitudes displacement should not be a measureable problem in this project. Although we believe that the quality of the photointerpreted vegetation overlays was acceptable for this project, no formal accuracy assessment was performed. Clearly, the vegetation overlays contain mapping errors which will have some impact on the results, although again we believe that this impact was very minimal. Future researchers should consider the importance of photographic properties if images are going to serve as the major source of spatial information.

The digitizing procedure and the processing algorithms also created some difficulties for future researchers to take note of. The first step in the digitizing procedure was to register the map to some ground measuring system. Because a precise Earth-reference was not necessary in this project, we used the plot corners and TRANSFORM command as previously described. We acknowledge that this is not the most precise procedure for ground referencing because this command uses a simple affine

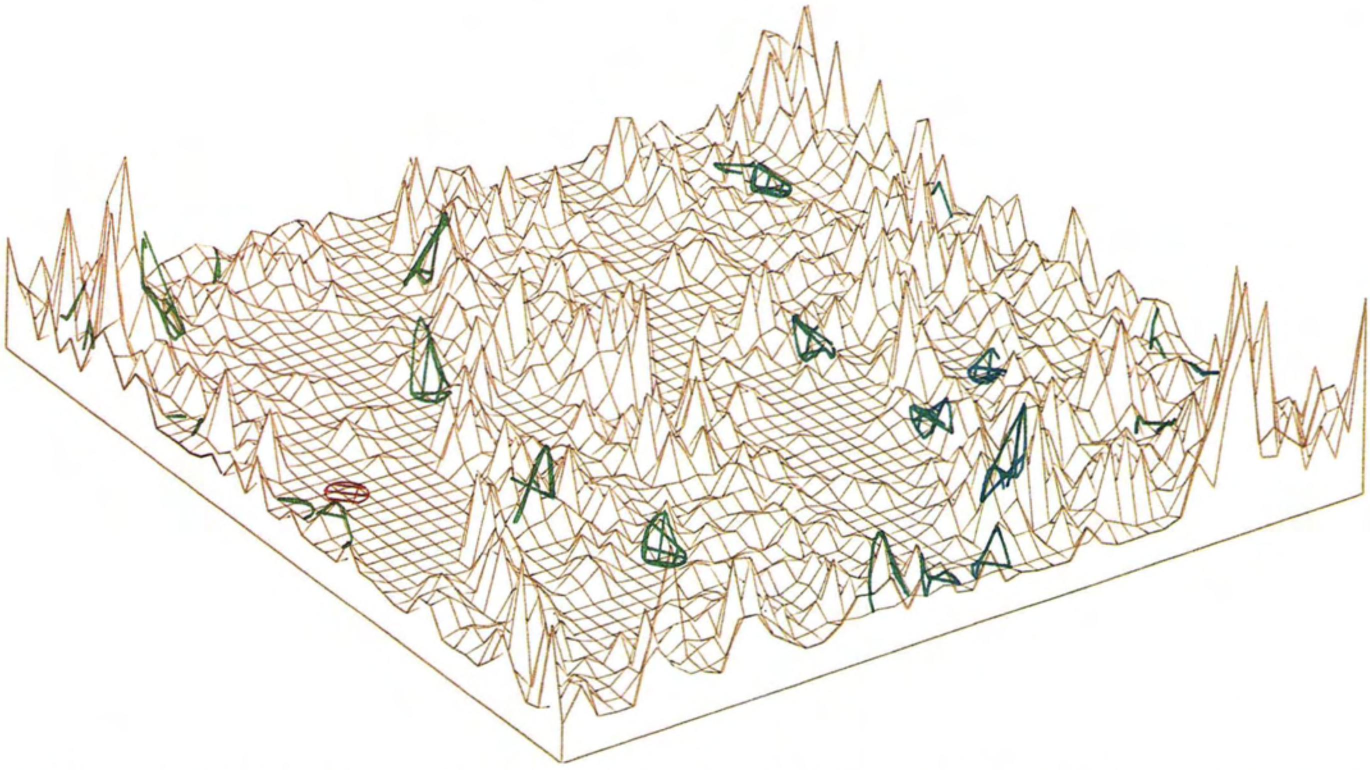

PLATE 1. Shrub crown cover percentage for Plot 1 displayed as a three-dimensional surface with numbers of animals trapped in the first post-application trapping session draped on the surface. Green indicates one animal trapped; red indicates two animals trapped.

transformation. We believe that this was acceptable here, partially because these plots were small in geographic extent. This simple transformation may not be exact, but all features should have been transformed the same relative to each other. Relative position was important in this project, not absolute position. If an absolute, Earth-referenced position is important, a different procedure may be necessary. When plots are established, surveying or GPS should be used to establish local control for registration.

Next, the locations of the features (point crowns, polygon crowns, traps) had to be entered into the spatial database. Point crowns and traps are point features, with no inherent topology. However, the polygon crowns do have an implicit topology, i.e., they each had to close. At digitizing scale (1:700), some of these crowns were extremely small and highly irregular. When attempting to close these features using the CLEAN command, the values for fuzzy tolerance and dangle length became very important. Because there were thousands of crowns, a fuzzy tolerance that was very small would leave too much manual work to do. If fuzzy tolerance was too large, crowns were reshaped or even sometimes collapsed to a line if they were long and narrow in shape. Thus, we had to try several sets of parameter values, which was time consuming.

Our final data set was cleaned with a fuzzy tolerance of 0.25 m, which was approximately 0.01 inches (0.25 mm) at map scale. After building the topology, we now know, at best, crown arc positions to within 0.25 m, which produces some imprecision in the values computed from the data set. Other researchers or practitioners who use GIS in a similar vein will need to take these limitations into account at the planning stage.

There are substantive benefits from the use of aerial photography and GIS in these types of studies. There is little question that there would not be a spatial data base of this complexity and extent without aerial photography and GIS. How else could more than 400 trap locations, and more than 22,000 crowns locations be measured and stored, and each linked to its associated characteristics which were vital to this assessment? Although technically possible, it is highly unlikely that any organization could have afforded the time and dollars it would have required to measure the values in the field that we have in the final database.

The time required to create this database using the aerial photography and GIS was 375 person-hours for photointerpretation and digitization, and 240 person-hours for editing and analyzing data, for a total of 615 person-hours. The use of GIS and aerial photography creates significant efficiencies in these exploratory situations which, in our opinion, far outweigh the disadvantages we have identified. These disadvantages primarily apply to the accuracy of the spatial data, and it is well to remember that field-collected information also contains measurement errors of significant size, so the trade-off may be minimal.

The GIS allowed us to cross-reference trap locations and trapping results with the vegetative community in the vicinity, something that is difficult to do manually. Further, many of the display products which were or will be used by the modelers, such as the perspective plots and drapes, would be almost impossible to create outside of a GIS. Aerial photography and GIS created functional efficiencies and capabilities which may make an impossibly expensive or impossibly complex procedure indeed possible.

CONCLUSION

In our opinion, aerial photography and GIS provide unprecedented opportunities for exploring spatial relationships between floral and faunal populations, and human activity. The effectiveness of these evaluations, in a cost sense and a scientific sense, can be enhanced through the use of these tools, if they are well understood and well utilized.

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REFERENCES

Agee, J. K., and S. C. Stitt, 1989. A geographic analysis of historical grizzly bear sightings in the north Cascades. *Photogrammetric Engineering & Remote Sensing* 55(11):1637-1642.

Donovan, M.L., D. L. Rabe, and C. E. Olson, 1987. Use of geographic information systems to develop habitat suitability models. *Wildlife Society Bulletin* 15:574-579.

Heinen, J. L., and J. G. Lyon, 1989. The effects of changing weighting factors on wildlife habitat index values. *Photogrammetric Engineering & Remote Sensing* 55(12):1445-1447.

Johnson, L. B., 1990. Analyzing spatial and temporal phenomena using geographic information systems. *Landscape Ecology* 4(1):31-43.

Needham, T. D., and J. L. Smith, 1987. Stem count accuracy and species determination in loblolly pine plantations using 35-mm aerial photography. *Photogrammetric Engineering & Remote Sensing* 53(12):1675-1678.

Stevens, P. D., 1989. *Acute Toxicity and Inhibition of Cholinesterase Activity in Small-Mammals Following Exposure to mathamidopbos*. M.S. thesis, Department of Fishery and Wildlife Biology. Colorado State University, Fort Collins, Colorado. 51p.

Stutheit, J., 1989. Gap analysis: GIS studies wildlife biodiversity. *GIS World* 2(5):40-42.

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Jae K. Lee, Richard A. Park, and *Paul W. Mausel,* Application of Geoprocessing and Simulation Modeling to Estimate Impacts of Sea Level Rise on the Northeast Coast of Florida.
David M. Stoms, Effects of Habitat Map Generalization in Biodiversity Assessment.
R. Welch, M. Remillard, and *J. Alberts,* Integration of GPS, Remote Sensing, and GIS Techniques for Coastal Resource Management.
Sally Westmoreland and *Douglas A. Stow,* Category Identification of Changed Land-Use Polygons in an Integrated Image Processing/Geographic Information System.