A PRACTICAL APPLICATION OF SATELLITE IMAGERY TO TO WILDLIFE HABITAT EVALUATION

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Abstract: Wildlife scientists have been challenged for many years with the need to develop cost effective techniques for evaluating wildlife habitat. This study sought to develop such a technique utilizing LANDSAT digital imagery. The criterion on which the analysis system was based was vegetative cover diversity (VCD). In order to assess the applicability of the results of the VCD index as a measure of habitat productivity, ground-generated vegetative and faunal diversity data were collected and compared to the VCD index. Comparisons were made for 19 plots of 65 ha each. VCD correlated positively ($P < 0.05$) with both plant species diversity (PSD) and faunal species diversity (FSD) for the plots overall. This analysis indicates that the use of computer manipulated LANDSAT digital data is a valid technique for evaluating wildlife habitat.

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A challenge which has confronted wildlife biologists for many years is the need to develop cost-effective techniques for assessing the real and/or inherent biological values of specific land or water areas. This problem has been brought into sharper focus with the on-going development of ecological planning and evaluating procedures by Hickman (1974) and similar developments by other resource management agencies and institutions. Most approaches to habitat classification and evaluation appear to be largely experimental.

Many wildlife ecologists have, in recent year, sought to apply many sophisticated advances to persistent problems of wildlands management and evaluation (Giles 1969:73, Adams 1969:92). One of the most promising of these advances is satellite imagery. This study was conducted in an effort to investigate the feasibility of utilizing LANDSAT-1 satellite imagery in wildlife resource evaluation.

The LANDSAT-1 satellite was launched in July 1972 into a sun-synchronous orbit, approximately 940 km above the earth's surface. Coverage is repeated every 18 days for every point on earth. The major data-gathering system aboard LANDSAT-1 is a multispectral scanner (MSS) which senses in 4 electromagnetic bands [i.e. green (0.5-0.6 um), red (0.6-0.7 um), near infrared[1] (0.7-0.8 um), and near infrared[2] (0.8-1.1 um)].

A number of studies have applied LANDSAT data to land resources, and more specifically wildlife habitat analysis. Most of the earlier wildlife work utilizing LANDSAT was restricted to wetland applications using photographic imagery (Work, et al. 1973), Cowardin and Myers 1974, Work and Thompson 1974, Work, et al. 1974a and 1974b). More recently various studies applied LANDSAT data (including digital data) to the analysis of terrestrial land-use and wildlife habitat parameters in various biomes (Rogers, et al. 1975, Anderson, et al,. 1976, and McKeon, et al. 1977).

As an integral part of a wildlife resource evaluation study in northcentral Oklahoma, LANDSAT-1 digital satellite imagery data were used to develop an index to wildlife habitat diversity, and determination of vegetative cover. The results of the habitat (vegetative cover type) diversity index were then tested (linear correlation analysis) against faunal data collected from the study area by more conventional means. The major objective of this phase of the project was the development of a technique for reliable analysis of a terrestrial resource unit's potential for support of wildlife populations utilizing satellite imagery.

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MATERIALS AND METHODS

The study was conducted on the portion of the Lake Carl Blackwell Land Use Area (LCBLUA) south of Highway 51 which comprises approximately 2,330 ha of tall grass prairie and post oak-blackjack oak forest in northwestern Payne County, northcentral Oklahoma.

Three principle vegetative cover types are present on the study area: upland hardwood forest, bottomland hardwood forest and native grassland. Climax plant species in these cover types include post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) in the upland forest, chinkapin oak (*Q. muehlenbergii*), elms (*Ulmus* spp.), hackberry (*Celtis occidentalis*), burr oak (*Q. macrocarpa*), and post oak in the bottomland forest and big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), and switch grass (*Panicum virgatum*) in the native grassland.

Average annual precipitation is approximately 82 cm. The climate is characterized as continental warm summer with extremes of temperature, wind and precipitation being common (Myers 1976). The average annual temperature is 16 C; the growing season approximates 210 days (Environmental Data Service 1972). The LCBLUA is owned by the Oklahoma State University and administered in part by the Oklahoma State University Business Office which has authority over leased grazing lands and recreational enterprises. The major land use on that portion of the LCBLUA which makes up the study area (since 1954) is a livestock grazing.

The well-being of any wildlife population is determined by the presence of suitable habitat, and especially by the distribution of various vegetative cover types (Giles 1969, Frye 1973). The distribution of the vegetative cover types on the study area was determined by analyzing various early (c. 1940) vegetation and soils maps plus aerial photographs (Agricultural Stabilization and Conservation Service (1969) and classification of MSS digital data collected by the LANDSAT-1 satellite. Satellite digital data (scene 1256) used in this study were collected 5 April 1973.

In order to utilize these MSS digital data in determining cover type distribution, various analysis and refinement techniques were employed. Since the data were given as a matrix of reflectance values, i.e., a vector of 4 for each pixel (picture element), a multivariate statistical analysis technique which linearly explains variance structures (principal component analysis, Morrison 1967) was helpful in interpreting the data matrix. Using this technique, principal component values were generated for each vector, such that the first described a line in 4 dimensional space which lies along the pathway of the greatest amount of linear variance in the data set. Since the first 2 principal component values explained virtually all of the variation (99%) in the data set, these numerical values were used to classify each pixel or matrices of pixels (e.g., 1 x 1, 2 x 2, or 3 x 3 matrices) within that scene into divisions (classes). This was accomplished by assigning windows (value ranges) around the first 2 principal components into which the value of a pixel must fall in order to be accepted into a specific class. This procedure is termed unsupervised classification. In this study, 6 classifications were used, corresponding to 6 cover types (native grassland, brush, disturbed sites, water, bottomland hardwoods and upland hardwoods). The ranges about the principal components were determined through ground-truthing and comparison of computer-generated maps with existing vegetative conditions and distribution.

A tool for comparison of potential productivity among the various portions of the study area was desired. Yoakum and Dasmann (1969) and Baxter and Wolfe (1973) have stated that the amount of edge between vegetative cover types on a given area is a definitive expression of habitat quality. Extending this logic, MacArthur and MacArthur (1961) and Karr and Roth (1971) used a measure of vegetative diversity as the basis for comparison in their studies of avian diversity. From the results of the classification of the LANDSAT-1 MSS data, a vegetative cover diversity (VCD) index (H) was computed for each of 40 65 ha tracts defined on the study area. The following formula was used in computing the diversity index (Shannon and Weaver 1964).

$$H = -\Sigma \left(\frac{ni}{N}\right) \log_e \left(\frac{ni}{N}\right)$$

where n_i = number of pixels within the i tract (a subunit of distinct vegetative cover type within a plot)

N = total number of pixels within a plot

$\log_e$ = natural logarithm.

Homogeneous tracts of a given cover type were used for diversity calculations rather than the total area of each cover type in order to gain a more realistic comparison of the amounts of edge within plots. In this manner, VCD index values were derived for each plot.

All plots on the study area were then stratified by VCD index value into 5 groups by dividing the range of diversity values (1.61 to 3.70) into 5 equal parts from the lowest to the highest.

Faunal and dominant plant species diversity (PSD) were measured on selected plots within each cover diversity group in order to test relationships among the three parameters. MacArthur and MacArthur (1961) found significant positive correlation (linear) between vegetative diversity and avian diversity. The faunal and plant species data were collected from transect routes (9 per plot) 805 m in length on which experienced observers walked, recording species of birds and mammals (including sign, i.e. tracks, feeding sign, dens, scats, and remains) and dominant plant species (observed per 91.4 m (100 step) interval. These data were collected from 19 of the 40 plots on the study area. Overall faunal and dominant PSD index values were obtained for each sampled plot again by using the Shannon-Weaver formula (N deleted, making formula applicable to a sample). In order to observe any relationship similar to that found by MacArthur and MacArthur (1961) and Karr and Roth (1971), product moment (linear) correlation analysis (Steel and Torrie 1960) was applied to diversity index values obtained from the 3 parameters sampled (by sampled plot).

RESULTS

A total of 2,330.18 ha were measured using LANDSAT-1 digital data. This represented a difference of 19.82 ha from the area of the study area listed by the Oklahoma State University Business Office, an error of only 0.86 percent.

Six classes resulted from the LANDSAT-1 classification system. These correspond to the vegetative cover types shown in Fig. 1. The total area and percentage of the total area of each cover type for the study area are shown in Table 1 along with the number and percentage of distinct vegetative cover type units (tracts) for the study area. These results corresponded well with ground truth data obtained during transect sampling (approximately 90% accuracy when compared with transect vegetative data collected by 100 step interval.

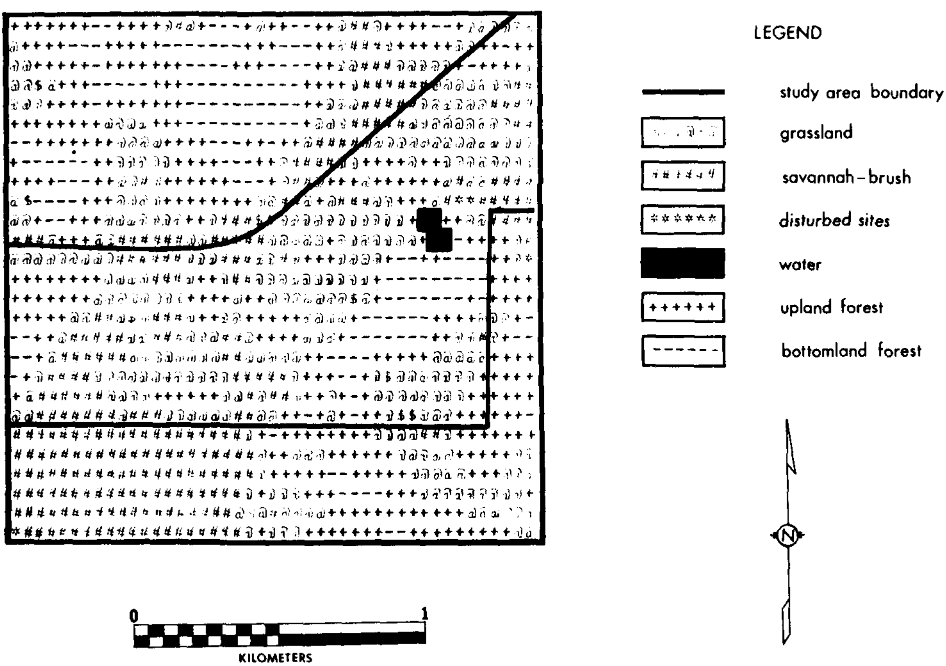

Fig. 1. Computer-generated vegetative cover type map of the study area (from LANDSAT-1 digital imagery data).

Table 1. Area of cover types and number of tracts on the study area (LANDSAT-1 data).

Classification	*Total area each type (ha)*	*Percent of total area*	*Number of distinct tracts*	*Percent of all tracts*	*Mean size of units (ha)*
Upland hardwood forest	889.45	38.6	170	25.8	5.23
Native grassland	598.86	25.7	196	29.8	3.02
Bottomland hardwood forest	442.74	19.0	98	14.9	4.47
Brush	286.61	12.3	131	19.9	2.16
Disturbed	60.58	2.6	45	6.8	1.33
Water	41.94	1.8	18	2.8	2.29
TOTALS	2,330.18	100.0	658	100.0	3.50 (Avg.)

Each plot on the study area was then evaluated in terms of its VCD as described above. VCD index values ranged from 3.70 (high diversity, interspersion) to 1.61 (low diversity, interspersion) with a mean of 2.74. The stratification of the plots by VCD index values into 5 groups yielded the basis for ground-based sampling of plant and animal community diversity. Nineteen plots were chosen at random for sampling by the sign-count transect technique described above. The minimum number of plots selected from any one stratum was 2 (from stratum 2). The distribution of the plots by VCD strata is presented in Fig. 2.

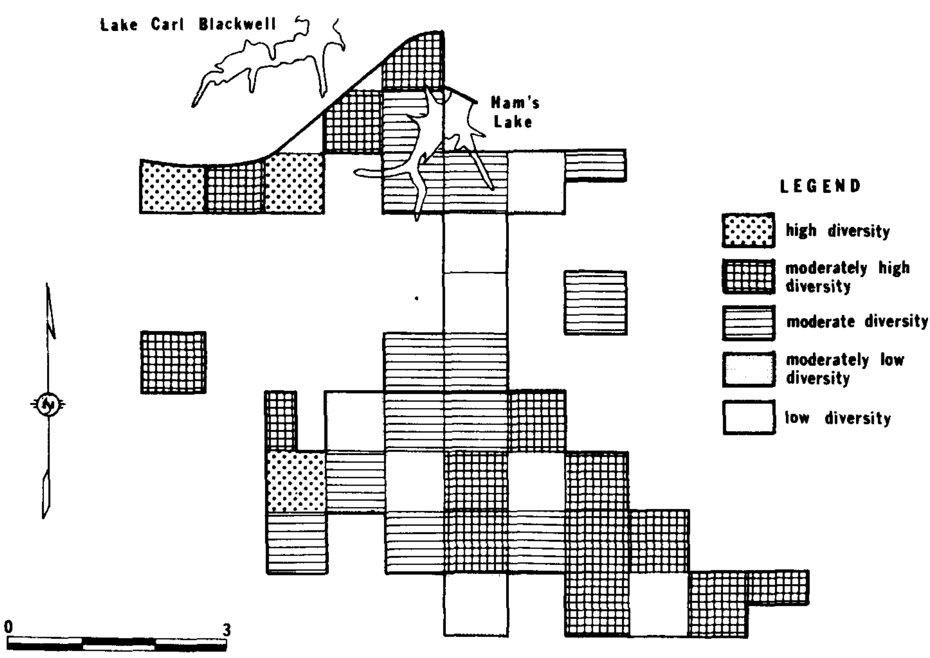

Fig. 2. Average vegetative cover diversity by stratum for each 65 ha unit (plot) on the study area (from LANDSAT-1 data).

Results of the dominant plant species survey (data collected during sign count transect sampling) indicated the flora most often encountered on the study area in each major vegetative cover type. A total of 4,617 observations were made of dominant plant species. The native grassland was dominated by little bluestem, ragweeds (*Ambrosia* spp.) silver bluestem (*Andropogon saccharoides*), red cedar (*Juniperus virginiana*), Indiangrass and three-awns (*Aristida* spp.). Smooth and winged sumacs (*Rhus glabra, R. copallina*), sandplum (*Prunus angustifolia*), elms and red cedar were predominant in the grassland brush (brush) cover type. Disturbed sites contained mostly three-awns, broomweed (*Gutierrezia dracunculoides*) and bare soil. The bottomland hardwood forest was dominated by burr oak, chinkapin oak, post oak and elms, while the most abundant species of the upland hardwood forest were post oak, blackjack oak, red cedar and buckbrush (*Symphoricarpos orbiculatus*). Water areas were not sampled during the sign-count transect survey but were surveyed using other rpocedures. A dominant PSD index value (using Shannon-Weaver formula) was calculated for each sampled plot. Index values ranged from 4.63 (very high) to 3.15 (moderately high) for the plots sampled. The mean was 3.93.

The bluejay (*Cyanocitta cristata*), Carolina chickadee (*Parus carolinensis*), bobwhite quail (*Colinus virginianus*), blue-grey gnatcatcher (*Polioptila caerulea*) and tufted titmouse (*Parus bicolor*) were the most common avifauna species encountered. The armadillo (*Dasypus novemcinctus*) eastern fox squirrel (*Sciurus niger*), raccoon (*Procyon lotor*), eastern cottontail rabbit (*Sylvilagus floridanus*) and white-tailed deer (*Odocoileus virginianus*) were the dominant mammals on the study area. A faunal species diversity (FSD) index value was calculated for each sampled plot. Bird and mammal data were combined for these calculations. The index values ranged from 4.99 to 3.60 with a mean of 4.19. Observations of individual birds and mammals totaled 2,015 and 1,144, respectively.

In order to test the validity of applying the VCD index as a habitat evaluation technique, linear correlation analysis was performed to determine the relationships among PSD, FSD, and VCD. Since it has been shown by various workers (Karr and Roth 1971, MacArthur et al. 1966, MacArthur and MacArthur 1961 and others) that the diversity of habitat (particularly vegetation features) directly affects the diversity of animal life, it was felt that a significant ($P < 0.05$) positive linear correlation relationship between VCD and FSD would essentially prove the credence of this habitat evaluation system. To further check the system's validity PSD was also used in the correlation analysis. Weaver (1968) states that the number of dominant plant species is associated with range condition which affects carrying capacity and diversity of animal life.

Significant ($P < 0.05$) linear correlation relationships did result among the 3 sampled parameters. The distributions of the mean PSD and FSD index values plotted against the VCD strata are shown in Fig. 3. The higher mean FSD encountered for

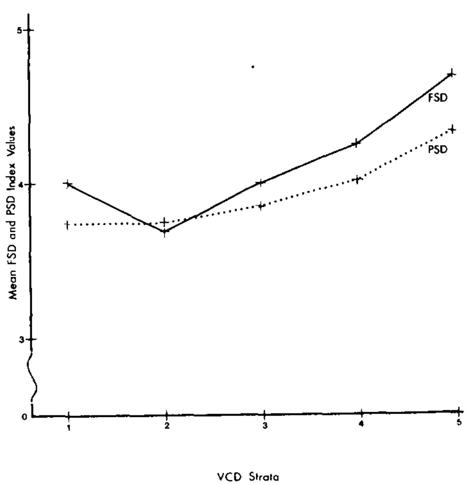

Fig. 3. Mean vegetative cover diversity (VCD), dominant plant species diversity (PSD) and faunal species diversity (FSD) for each VCD stratum.

stratum I may be explained partially as the result of observer bias and in part by the proximity of the low diversity plots to plots of much greater diversity. Observer bias resulted from changes in the number and composition of observers which remained rather constant for the other plots sampled. PSD follows the expected steady increase for each succeeding VCD stratum. The greater the number of tracts within each cover type the greater is the chance for variation in the dominant plant species present due to edaphic changes and/or changes in land use pressure.

DISCUSSION

The major objective of this study was the development of a wildlife habitat evaluation technique using computer manipulated satellite imagery. In showing the results of the LANDSAT classification and analysis system to correspond (correlate) significantly with ground-generated faunal and vegetative data in documented fashion, a basis has been laid for the acceptance of the system and fulfillment of the objective. With the aid of a computerized habitat evaluation system (such as described) the wildlife scientist could determine the location and extent of areas critical to wildlife. Manpower is not usually available to allow ground-based surveys of wildlife habitat parameters on a state or region-wide basis. Therefore, remotely sensed data such as LANDSAT digital imagery may play a very functional role in future wildlife management.

Care should be taken in evaluating an area's wildlife potential merely on the results of LANDSAT classification, however. The quality of any tract of a specific cover type may be misinterpreted by the observer. On the other hand, results of a measure of interspersion such as the diversity calculation used in this study may be more reliable in comparing areas of similar size. Although the results of the classification and diversity computations agreed well in this study, it is essential to ground-truth at least a portion of the study area to assure reliability.

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