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FINAL REPORT

W-106-R

Cooperative Upland Wildlife Project (Phase II)

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Illinois Department of Natural Resources

August 1995

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FINAL REPORT

State of Illinois

W-106-R

Project Period: 1 July 1992 through 30 June 1995

Study: Cooperative Upland Wildlife Project (Phase II)

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Need: As noted in Phase I of Project W-66-R, the quality and quantity of upland wildlife habitat in Illinois are determined primarily by agricultural land use, and expanding row-crop production in recent decades has critically affected habitat for upland wildlife. Moreover, problems of soil and water degradation associated with intensive row-cropping, and the chronic over-production of farm commodities, have gained wide recognition by the public during the past decade. Phase I of the project considered emerging farm policies and programs relative to habitat conditions and the abundance of upland wildlife species in Illinois, especially the bobwhite, ring-necked pheasant, and cottontail. The preliminary findings of Phase I indicate that the Illinois Department of Natural Resources (IDNR) must develop habitat programs that recognize and accommodate regional variations in agricultural land use and habitat priorities. Phase II of W-66-R is directed to developing the

information and technologies that will be necessary for the IDNR to deliver effective regional habitat programs.

Objectives:

1. Describe and predict responses by key upland wildlife species (especially the bobwhite and pheasant) to regional habitat conditions.

2. To preliminarily develop the analytical, informational, and technological infrastructure which will enable the IDNR to put in place management strategies on a regional basis in Illinois.

EXECUTIVE SUMMARY

This Project represents a cooperative effort between staff of the Illinois Natural History Survey (INHS), Center for Wildlife Ecology and the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale. This report reflects only those Jobs for which the latter organization was partly or solely responsible.

Job 1.1 (Classification of land use/habitat information from remotely sensed data) was designed as a fully collaborative effort. We planned to develop the classification from statewide coverage of Landsat TM scenes selected by INHS staff. Also, we assumed that INHS staff with expertise in classification of

Landsat TM scenes would be active participants and would lend technical support to this task. Indeed, we anticipated that a complete classification would be available by the end of Segment 4 so we could focus resources on other tasks planned under Study 1 (Remote Sensing and Habitat Modeling for Upland Wildlife).

Because of unanticipated staff departures it became clear that the INHS would not participate in developing a statewide classification, and SIUC staff would have to assume sole responsibility. Following consultations with IDNR Program Managers, we made completion of a statewide classification the priority objective of Study 1 and used all available resources to complete that task. The scope and complexity of producing a land cover classification for Illinois using PC software was further complicated by limitations of the Landsat TM data available for the project thru the INHS. This added problem was not resolved until Segment 6 when SIUC's Morris Library acquired Landsat scenes of most portions of Illinois that were better suited for land cover classification than the original scenes we had to work with.

Despite these unanticipated complications, all of the planned objectives of this project were substantially completed with minor exceptions. Objectives 1 and 2 of Job 1.1 were met

with the completion of a computerized statewide land cover classification of Illinois at 30 x 30 m ground resolution. This classified image is stored on optical disks at the Cooperative Wildlife Research Laboratory. Individual county files will be distributed to IDNR personnel as needed. Objectives 1 and 2 of Job 1.2 and objective 1 of Job 1.3 were met with the development and delivery of an interactive computer program for the graphic display, analysis, and modeling of landscape-level habitat conditions. A photocopy of the Habitat Analysis and Modeling System (HAMS) user's guide and reference manual is appended to this report. Objectives of Jobs 2.1 and 2.2 were also met and the results presented in the report. Jobs 2.3 and 2.4 were the sole responsibility of the INHS and will be reported separately by that agency. The objectives of Job 3.1 (Analyze and Report) were met through the timely preparation and distribution of prior Annual Performance Reports and this Final Report.

STUDY NO. 1: **Remote Sensing and Habitat Modeling for Upland Wildlife**

Job 1.1: **Classification of land use/habitat information from remotely sensed data**

Objectives: (1) To investigate the potential utility of various remotely sensed data sources for obtaining land use/habitat information over broad geographic areas; (2) to investigate alternative methods to classify remotely sensed data into usable land use/habitat categories.

INTRODUCTION

The powerful tools of remote sensing and geographical information system (GIS) software afford resource managers opportunity to develop large data bases that can provide the quantity and quality of information needed for resource management and landscape and regional scales. A land use/land cover classification is a prerequisite foundation upon which resource managers can build GIS data layers that describe location and relative quality of habitat and its spatial relationship with other landscape attributes.

Our investigations of alternative techniques for the inventory and analysis of upland habitat from remotely sensed

data quickly revealed that only satellite imagery was suitable for statewide coverage. The fortuitous availability of statewide Landsat 5 TM coverage for project use made that the imagery of choice.

Differentiation of land use/land cover types approximated a Level I classification (Anderson et al. 1976). Categories resolved were cropland (row crops and small grains), woods (coniferous, deciduous, late oldfields), orchards, developed areas, water, and grassland (all other herbaceous vegetation). This level of classification was necessitated by the less-than-optimum Landsat TM scene dates originally available for the project. Multi-temporal data (scenes from different parts of the same growing season) would likely permit a level of classification more appropriate for upland habitat analysis.

METHODS

Data Sets

Landsat 5 TM Data.--Initially, satellite imagery purchased by the Illinois Natural History Survey was used for this project. This satellite coverage of Illinois consists of 9 full and 2 quarter scenes that are geographically referenced, terrain corrected and mosaicable. The INHS scene dates range from May

1988 to June 1991 (Fig. 1). Data were acquired in TM Fast format on 8 mm Exabyte tapes from INHS. Many of these scenes were difficult to classify which led to a large amount of confusion between several land use classes.

For these confused areas, we used additional satellite imagery owned by the Cooperative Wildlife Research Laboratory (CWRL), and SIUC's Morris Library. These additional scenes range in date from 10 September 1992 to 3 October 1993. Each county classified, the satellite imagery used, and the scene dates are listed in Table 1.

TIGER/Line(TM) Census Files.--TIGER (Topographically Integrated Geographic Encoding and Reference System) is a digital map base used to support Census Bureau programs. The 1990 Census TIGER/Line files contain digital data for features such as streets, rivers and streams, railroads, and political boundaries. The TIGER data set for all Illinois counties was acquired from SIUC's Morris Library.

Aerial Photography.--National Aerial Photography Program (NAPP) 1988, black and white, 1:40,000 scale positive prints available for all of Illinois was the main source for verification of land use classes. A complete set of photographs was made available for the project by Morris Library at SIUC.

Color infrared prints from the CWRL map library were used to verify classifications in some areas. Sets of NAPP black and white contact print enlargements (3x) that covered bobwhite and pheasant call count routes in 90 counties were provided by the IDNR. These photos, with accompanying ground truth information, were used for accuracy assessments of each county's satellite classification.

USGS Topographical Maps.--U.S. Geological Survey 7.5-minute quadrangle maps were obtained from both SIUC's Morris Library and the CWRL map library. The most recent copies of these maps were used to identify and digitize orchards in counties that had significant amounts of this land use type. In some cases they were also used to verify other land use types.

Classification Scheme

Six land cover types were identified (crop, woods, grass, water, developed, and orchards) generally similar to the complexity of a classification described as Level 1 by Anderson et al. (1976). Crops included all cultivated acreage in row crops and small grains, as well as miscellaneous cultivated crops. Woods included coniferous forest, deciduous forest, and late old fields. Grass included hay, pasture, fallow fields,

Conservation Reserve Program (CRP) fields, field edges, lawns, roadsides, and any other herbaceous cover not considered crop. Water included lakes, rivers, ponds, and other areas with permanent water. Developed areas were defined using TIGER data. Orchards were defined from topographic maps.

Preprocessing

Preprocessing Landsat TM data consisted of importing raw files into Map and Image Processing System (MIPS, MicroImages Inc., Lincoln, NE) software (Miller et al. 1989). Polygons defining broad natural divisions adapted from Schwegman (1973) were digitized over satellite imagery and plotted to binary rasters coregistered to the original scene. These binary rasters were used to extract natural divisions within each scene to limit spectral variability for automatic classification. Cumulus clouds and their shadows were delineated with polygons using the satellite images as a reference. The polygons were plotted to coregistered binary rasters which were used to remove them from the classification to also limit spectral variability.

A principal components analysis was performed on bands 1, 2, and 3 for each natural division and the first principal component (PC1) was saved. A Normalized Difference Vegetation Index (NDVI)

also was calculated (Lillesand and Kiefer 1987). Spectral Bands 4, 5, 7, PC1 and NDVI were input in MIPS to an ISOCLASS algorithm which generated approximately 200 ISOCLASS output classes.

TIGER data were processed to provide coregistered maps of developed areas and primary and secondary highways which were combined with the isoclassification of the satellite data. Developed areas were delineated using neighborhood roads extracted from TIGER files and plotted to a false color composite image of each scene. A vector of the Illinois state boundary was edited over this image and polygons were drawn around clusters of neighborhood roads. These polygons, which represented developed areas, were cross referenced with hard copy maps of Illinois and defined the "developed" habitat class. Visible quarries and other development areas were also identified in this fashion and put into the developed class.

Primary and secondary highways were extracted from TIGER files for each county within a scene and mosaicked. Primary highways were plotted to a coregistered binary raster and given a width of 2 pixels and digital value of 1. Secondary roads were plotted to the same binary raster, given the same digital value, but with a width of 1 pixel. The polygons representing developed areas were also plotted using this binary raster with a value of

1 on the inside. This binary raster, representing highways and developed areas, was combined with the results of the isoclassification so that developed areas and highways had a digital value of 205 and a distinct color.

Orchards could not be classified using the satellite imagery, but they were identified from USGS 7.5-minute quadrangle maps. The 1992 agricultural census (U.S. Dep. of Commerce 1994) revealed that 23 counties that had more than 48 ha of orchards accounted for 73% of Illinois orchards. Orchards were manually digitized using the maps for these 23 counties (Appendix A) and combined with their respective county classification.

Classification Procedures

After the initial automatic classifications were run and the ancillary TIGER data added, results (approximately 200 isoclasses) were grouped into meaningful information classes or land use types. We tested 2 methods for lumping classes. The first used 1-mile^2 (2.59-km^2) sample boxes systematically placed over the satellite scene at 10-mile (16.1-km) intervals for ground truth data acquisition. Sample boxes then were delineated on acetate overlays for NAPP black and white positive prints.

The land-use classes interpreted within each sample box were drawn onto the acetate overlay.

The land use for each sample box was then digitized to a coregistered raster using the raw satellite image as a reference. These data were used to lump the isoclasses into information classes based on the correlation of the ISOCLASS values to the digital ground truth data within each sample box. This method proved to be time prohibitive for the large area to be classified and was discontinued.

Alternatively, we examined individual ISOCLASS values for a particular scene and natural division, and used photo verification to determine the most prevalent land use class associated with each ISOCLASS value. Color for each ISOCLASS value was assigned to emulate a false color image. Each ISOCLASS was then flashed and the most prevalent land use associated with that ISOCLASS value was determined. Information about the amount and type of confusion associated with each ISOCLASS value was recorded. After extensive photo verification, we found that many of the resulting ISOCLASS values were confused between 2 or more land use classes.

Each natural division of each scene was reviewed and only ISOCLASSES that showed little or no confusion were retained. A

binary raster was created indicating the location of all the confused ISOCLASSES for each scene and natural division. These areas were then re-classified using a maximum likelihood classifier to calculate the statistical probability of a given pixel belonging to a particular land use class (Lillesand and Kiefer 1987). The results of this classifier were combined with the unconfused results from the isoclassification and evaluated. As an initial accuracy assessment, the percent of land cover types for each extracted county was compared to existing estimates of land use. If these estimates varied from our classification by >10% the county was evaluated using aerial photos.

Even after reclassifying these scenes, acceptable accuracies were not attained for many counties. These counties were then individually re-classified, using only the maximum likelihood classifier. Counties that were not yet processed also were individually classified using the maximum likelihood classifier. Different satellite imagery, owned by the CWRL and SIUC's Morris Library, was then used for counties that still proved difficult to classify accurately. The majority of this imagery were autumn scenes taken in October that were much easier to classify.

After each county was extracted and spectrally classified, a contextual classifier was used to improve the classification. The contextual classifier was a series of FORTRAN programs that sequentially manipulated the classified output for each county. The first program detected single isolated pixels of any class and replaced them with the surrounding majority land use class. The program also removed linear crop features by replacing 1-pixel wide strips of crop, that had grass pixels on opposite sides with grass. The second program used output from the first to determine size of contiguous crop patches. This program created an output raster with pixel values representing the size of their respective patch. The next program replaced crop patches <13 pixels with the surrounding majority land-use class. The final program replaced any new single pixels created by the previous programs with the surrounding majority land-use class.

Accuracy Assessment

The classification accuracy of the completed counties was assessed using land cover information collected along 0.5-mile (0.8-km) wide and 20-mile (32.25-km) long quail and pheasant call-count routes. The land cover along these routes was identified and mapped on aerial photos by IDNR biologists via

field inspections during the summers of 1990 and 1991. Conservation Reserve Program (CRP) enrollment for each county was also recorded along each route.

Representative samples >3 ha of each land cover type were selected on the aerial photographs for each call count route. Between 50 and 90 samples per county were used depending upon the homogeneity of the landscape and meander of the route. These samples then were located on the classified county image and their land use types were compared. There were 6 pairs of counties (Gallatin-Hardin, Marshall-Putnam, Jasper-Clay, Stephenson-Winnebago, Carroll-Jo Daviess, and McDonough-Fulton) that had a single route extending across both counties. In these cases, the same set of sample points were used for both county accuracy assessments. An error matrix was constructed for each call count route and used to compute errors of omission and commission, overall accuracy, and the Kappa statistic (Congalton 1991). Accuracy assessment data sampled for each county also were pooled, without the duplicate sample points mentioned above, for statewide estimates.

RESULTS AND DISCUSSION

We classified 99 of 102 Illinois counties (Cook, Du Page, and Lake counties were not classified). The quality (accuracy) of each county classification varied with the quality and acquisition date of the satellite imagery used. Scenes originally acquired from INHS ranged in date from May 26, 1988 to June 10, 1991 and spanned from early spring to summer. The scenes acquired from SIUC's Morris Library ranged only from September 10, 1992 to October 12, 1992 and were much easier to accurately classify.

Overall classification accuracy ranged from 77% for Kendall County to 98% for Macon County and averaged 91.8% over all the counties (Table 2). The Kappa value ranged from 0.58 for Kendall County to 0.98 for Peoria County and averaged 0.88 over all counties. The woods and water classes were the most accurately defined; errors of omission and commission for woods averaged 2.1 and 1.5%, respectively. The errors of omission and commission for water averaged 3.8 and 0.1%, respectively. Average error estimates for crop and grass were notably higher. The errors of omission and commission for crop averaged 3.7 and 17.5% respectively, whereas omission and commission errors for grass averaged 23.6 and 6.4%, respectively. Accuracy assessment data sampled for each county also were pooled for statewide estimates

(Table 3). These estimates were very similar to the average county accuracy assessments. Overall statewide accuracy was 92% with a Kappa value of 0.88. Once again, woods and water were the most accurate with errors of omission and commission <3.0%. The errors of omission and commission for crop were 3.5 and 16.3%, respectively. Errors of omission and commission for grass were 23.4 and 6.0%, respectively.

Our statewide classification compared well with other land use classifications using Landsat 5 TM data. Sader et al. (1991) reported a 70% overall classification accuracy (93% for woods) for an area of Costa Rica. Airola and Vogel (1988) classified TM data for New Jersey and reported an overall accuracy of 91.8% (94.1% for woods and 82.4% for agriculture). Moore and Bauer (1990) reported an overall accuracy of 87% for their classification of TM data in northern Minnesota. Because our classification accuracy varied by county and by land use type, we have provided detailed estimates of accuracy for each county we reviewed (Appendix B).

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Table 1. Data on Landsat 5 TM scenes used to classify each Illinois county.

County	Scene1[a]	Scene2	Source	Date1	Date2
Adams	P24R32		INHS	06/24/90	
Alexander	P23R34		MORRIS	10/12/92	
Bond	P23R33		INHS	05/26/88	
Boone	P23R31	P24R31	INHS	06/30/89	06/24/90
Brown	P24R32		INHS	06/24/90	
Bureau	P24R31		INHS	06/24/90	
Calhoun	P24R33		INHS	04/24/91	
Carroll	P24R31		INHS	06/24/90	
Cass	P24R32		INHS	06/24/90	
Champaign	P23R32		INHS	05/26/88	
Christian	P23R33	P23R32	INHS	05/26/88	05/26/88
Clark	P22R33		INHS	06/10/90	
Clay	P23R33	P22R33	INHS	05/26/88	06/10/90
Clinton	P23R33		INHS	05/26/88	
Coles	P22R33		INHS	06/10/90	
Cook	P23R31		MORRIS	09/10/92	
Crawford	P22R33		INHS	06/10/90	
Cumberland	P22R33		INHS	06/10/90	
De Kalb	P23R31		MORRIS	09/10/92	
De Witt	P23R32		INHS	05/26/88	
Douglas	P23R32		INHS	05/26/88	
Du Page	P23R31		MORRIS	09/10/92	
Edgar	P22R32	P22R33	INHS	06/10/90	06/10/90
Edwards	P22R33		INHS	06/10/90	
Effingham	P23R33		INHS	05/26/88	
Fayette	P23R33		INHS	05/26/88	
Ford	P23R32		INHS	05/26/88	
Franklin	P23R34		MORRIS	10/12/92	
Fulton	P24R32		INHS	06/24/90	
Gallatin	P22R34		INHS	06/10/90	
Greene	P24R33		INHS	04/24/91	
Grundy	P23R31		INHS	06/30/89	
Hamilton	P22R34	P22R33	INHS	06/10/90	06/10/90
Hancock	P24R32		INHS	06/24/90	
Hardin	P22R34		INHS	06/10/90	
Henderson	P24R32		INHS	06/24/90	

Henry	P24R31		MORRIS	10/03/92	
Iroquois	P23R32	P23R31	MORRIS	10/12/92	09/10/92
Jackson	P23R34		MORRIS	10/12/92	
Jasper	P22R33		INHS	06/10/90	
Jefferson	P23R33		INHS	05/26/88	
Jersey	P24R33		INHS	04/24/91	
Jo Daviess	P24R31		INHS	06/24/90	
Johnson	P23R34		MORRIS	10/12/92	

Table 1. Continued.

County	Scene1[a]	Scene2	Source	Date1	Date2
Kane	P23R31		MORRIS	09/10/92	
Kankakee	P23R31		MORRIS	09/10/92	
Kendall	P23R31		MORRIS	09/10/92	
Knox	P24R32		INHS	06/24/90	
La Salle	P23R31		INHS	06/30/89	
Lake	P23R31		MORRIS	09/10/92	
Lawrence	P22R33		INHS	06/10/90	
Lee	P24R31		INHS	06/24/90	
Livingston	P23R32		INHS	05/26/88	
Logan	P23R32		INHS	05/26/88	
Macon	P23R32		INHS	05/26/88	
Macoupin	P23R33		INHS	05/26/88	
Madison	P23R33		INHS	05/26/88	
Marion	P23R33		INHS	05/26/88	
Marshall	P24R31		MORRIS	10/03/92	
Mason	P24R32		MORRIS	10/03/92	
Massac	P23R34		MORRIS	10/12/92	
McDonough	P24R32		INHS	06/24/90	
McHenry	P23R31		MORRIS	09/10/92	
McLean	P23R32		INHS	05/26/88	
Menard	P24R32		INHS	06/24/90	
Mercer	P24R31	P24R32	MORRIS	10/03/92	10/03/92
Monroe	P24R33		INHS	04/24/91	
Montgomery	P23R33		INHS	05/26/88	
Morgan	P24R32		INHS	06/24/90	
Moultrie	P23R32		INHS	05/26/88	
Ogle	P24R31		INHS	06/24/90	
Peoria	P24R32		INHS	06/24/90	
Perry	P23R34		MORRIS	10/12/92	

Piatt	P23R32		INHS	05/26/88	
Pike	P24R33	P24R32	INHS	04/24/91	06/24/90
Pope	P23R34		MORRIS	10/12/92	
Pulaski	P23R34		MORRIS	10/12/92	
Putnam	P24R31		MORRIS	10/03/92	
Randolph	P23R34		MORRIS	10/12/92	
Richland	P22R33		INHS	06/10/90	
Rock Island	P24R31		MORRIS	10/03/92	
Saline	P22R34		INHS	06/10/90	
Sangamon	P23R33		INHS	05/26/88	
Schuyler	P24R32		MORRIS	10/03/92	
Scott	P24R32		INHS	06/24/90	
Shelby	P23R33		INHS	05/26/88	
St. Clair	P23R34		MORRIS	10/12/92	
Stark	P24R31		INHS	06/24/90	
Stephenson	P24R31		INHS	06/24/90	

Table 1. Continued.

County	Scene1[a]	Scene2	Source	Date1	Date2
Tazewell	P24R32	P23R32	INHS	06/24/90	05/26/88
Union	P23R34		MORRIS	10/12/92	
Vermilion	P22R32		INHS	06/10/90	
Wabash	P22R33		INHS	06/10/90	
Warren	P24R32		INHS	06/24/90	
Washington	P23R33		INHS	05/26/88	
Wayne	P22R33		INHS	06/10/90	
White	P22R33	P22R34	INHS	06/10/90	06/10/90
Whiteside	P24R31		INHS	06/24/90	
Will	P23R31		MORRIS	09/10/92	
Williamson	P23R34		INHS	04/17/91	
Winnebago	P24R31	P23R31	INHS	06/24/90	06/30/89
Woodford	P23R32		MORRIS	10/12/92	

[a]P=Path, R=Row.

Table 2. Summary of land use classification accuracy assessment and percent errors of omission (O) and commission (C) for Illinois counties classified from Landsat 5 TM satellite data.

	Crop		Grass		Woods		Water		Accuracy[a]	
County	O	C	O	C	O	C	O	C	Overall(%)	Kappa
Adams	16	28	25	18	0	0	7	0	86	0.81
Alexander	no accuracy assessment									
Bond	no accuracy assessment									
Boone	0	10	4	0	0	0	22	0	97	0.95
Brown	8	19	22	9	0	0	0	10	92	0.88
Bureau	3	21	31	0	0	6	0	0	90	0.85
Calhoun	no accuracy assessment									
Carroll	6	6	5	10	6	0	0	0	95	0.93
Cass	3	16	26	5	0	0	0	0	92	0.89
Champaign	0	11	18	0	8	0	0	0	95	0.92
Christian	7	7	15	15	0	0	0	0	93	0.90
Clark	0	33	44	6	4	4	11	0	87	0.81
Clay	4	25	40	13	0	0	14	0	87	0.81
Clinton	8	23	35	10	0	7	0	0	87	0.82
Coles	0	21	38	0	0	0	0	0	91	0.87
Cook	no accuracy assessment									
Crawford	14	14	30	20	0	5	0	0	90	0.86
Cumberland	0	7	12	0	0	0	0	0	97	0.96
De Kalb	0	6	17	0	-	-	0	0	96	0.92
De Witt	0	24	24	6	38	0	0	0	87	0.80
Douglas	30	27	56	6	0	0	0	0	85	0.76
Du Page	no accuracy assessment									
Edgar	3	3	4	9	12	0	0	0	96	0.93

Edwards	4	17	14	5	0	0	8	0	94	0.91
Effingham	4	30	35	12	7	0	12	0	86	0.80
Fayette	0	23	25	0	0	0	0	0	93	0.90
Ford	0	5	10	0	0	0	0	0	97	0.96
Franklin	7	11	12	12	5	0	0	0	93	0.90
Fulton	0	38	45	15	10	5	17	0	83	0.76
Gallatin	0	19	14	0	0	0	0	0	95	0.93

Table 2. Continued.

	Crop		Grass		Woods		Water		Accuracy[a]	
County	O	C	O	C	O	C	O	C	Overall(%)	Kappa
Greene	no accuracy assessment									
Grundy	7	3	10	20	0	0	0	0	95	0.92
Hamilton	11	0	0	8	0	0	0	0	97	0.96
Hancock	0	6	4	13	0	0	75	0	92	0.88
Hardin	0	19	14	0	0	0	0	0	95	0.93
Henderson	0	38	53	0	0	6	33	0	84	0.76
Henry	0	5	12	0	0	0	0	0	97	0.96
Iroquois	3	6	18	0	0	11	0	0	95	0.91
Jackson	0	18	19	0	0	0	0	0	95	0.93
Jasper	4	25	40	13	0	0	14	0	87	0.81
Jefferson	4	39	43	5	0	0	0	0	87	0.82
Jersey	0	10	18	0	0	0	0	0	96	0.94
Jo Daviess	6	6	5	10	6	0	0	0	95	0.93
Johnson	12	25	9	4	0	0	0	0	95	0.93
Kane	0	12	20	0	0	0	0	0	95	0.93
Kankakee	0	12	25	0	-	-	0	0	93	0.86
Kendall	3	39	86	0	11	11	0	0	77	0.58
Knox	no accuracy assessment									

Lake	no accuracy assessment									
La Salle	0	31	36	0	0	0	0	0	88	0.83
Lawrence	0	18	17	6	5	10	50	0	89	0.85
Lee	0	12	27	0	0	0	0	0	95	0.93
Livingston	0	13	27	0	0	0	0	0	93	0.88
Logan	0	9	12	0	0	0	12	0	96	0.94
Macon	0	4	10	0	0	0	0	0	98	0.97
Macoupin	4	12	15	5	0	0	0	0	94	0.92
Madison	9	9	19	25	7	0	0	0	91	0.87
Marion	4	27	33	6	0	0	0	0	90	0.87
Marshall	0	6	20	0	0	0	0	0	96	0.94
Mason	3	45	74	5	0	6	8	0	80	0.71
Massac	0	17	14	0	0	0	0	0	96	0.94
McDonough	0	38	45	15	10	5	17	0	83	0.76

Table 2. Continued.

	Crop		Grass		Woods		Water		Accuracy[a]	
County	O	C	O	C	O	C	O	C	Overall(%)	Kappa
McHenry	no accuracy assessment									
McLean	no accuracy assessment									
Menard	no accuracy assessment									
Mercer	no accuracy assessment									
Monroe	5	33	37	5	0	0	0	0	88	0.84
Montgomery	6	24	31	15	6	0	0	0	89	0.85
Morgan	4	14	24	6	0	0	0	0	93	0.91
Moultrie	no accuracy assessment									
Ogle	0	17	17	4	7	13	22	0	90	0.86
Peoria	0	4	9	0	0	0	0	0	98	0.98
Perry	4	12	17	6	0	0	0	0	95	0.93

Piatt	0	7	9	0	0	0	0	0	97	0.96
Pike	4	8	10	5	0	0	0	0	96	0.95
Pope	12	25	9	4	0	0	0	0	95	0.93
Pulaski	4	4	6	6	6	6	0	0	96	0.94
Putnam	0	6	20	0	0	0	0	0	96	0.94
Randolph	4	8	11	11	4	0	0	0	95	0.93
Richland	4	20	31	6	0	0	0	0	92	0.89
Rock Island	3	10	14	5	0	0	0	0	95	0.92
Saline	0	50	52	0	0	0	0	7	85	0.80
Sangamon	2	2	6	18	11	0	0	0	96	0.93
Schuyler	18	7	15	38	0	0	0	0	90	0.87
Scott	8	4	5	10	0	0	0	0	96	0.94
Shelby	0	25	32	10	10	0	0	0	88	0.84
Stark	no accuracy assessment									
St. Clair	0	12	19	0	0	0	0	0	95	0.93
Stephenson	3	31	40	0	0	4	0	0	88	0.82
Tazewell	0	9	15	0	0	0	0	0	96	0.93
Union	16	10	15	23	0	0	0	0	92	0.89
Vermilion	0	6	12	0	0	0	0	0	97	0.95
Wabash	0	19	31	0	0	0	0	0	93	0.90
Warren	0	37	38	0	7	0	0	0	87	0.81

Table 2. Continued.

	Crop		Grass		Woods		Water		Accuracy[a]	
County	O	C	O	C	O	C	O	C	Overall(%)	Kappa
Washington	4	28	30	5	0	0	8	0	90	0.86
Wayne	14	46	57	10	0	15	0	0	81	0.75
White	12	29	42	17	0	0	0	0	85	0.79
Whiteside	4	19	26	10	5	0	0	0	89	0.84

Will	12	0	0	30	0	0	0	0	94	0.91
Williamson	14	27	24	12	0	0	0	0	89	0.85
Winnebago	3	31	40	0	0	4	0	0	88	0.82
Woodford	2	2	8	0	0	11	0	0	97	0.95

[a]The accuracy assessments are as follows:

Overall accuracy = the total number of fields correctly classified, divided by the total number of fields sampled, multiplied by 100.

Kappa statistic = A normalized accuracy assessment which accounts for fields correctly classified by chance (Congalton 1991).

Table 3. Accuracy assessment and error estimate[a] samples pooled for an overall statewide estimate of accuracy.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Crop	2134	65	12	0	2211	3.5	16.3	96.5
Grass	341	1144	7	1	1493	23.4	6.0	76.6
Woods	9	17	1331	0	1357	1.9	1.7	98.1
Water	10	7	4	674	695	3.0	0.1	97.0
Sum	2494	1233	1354	675	5756			

Overall Accuracy: 92% Kappa: 0.88

[a]Calculated according to Congalton 1991.

[b]Ground truth data from Illinois Department of Natural Resources quail and pheasant call count routes.

Appendix A. Counties with greater than 48 ha of orchards were digitized using USGS 1:24000-scale topographical quadrangle maps supplied by Morris Library. These 23 counties represent 73% of land in orchards. Cumberland County quad maps were unavailable (51.8 ha). The orchard vectors were merged into a single vector and then converted to a raster for each county.

County	Quad	Quad year	Area ha[a]
Union			730.5
	Anna	1978	
	Cobden	1990	
	Makanda	1990	
	Mill Creek	1990	
Jackson			552.8
	Carbondale	1990	
	Cobden	1990	
	Elkville	1978	
	Makanda	1990	
	Murphysboro	1978	
	Pomona	1990	
	Willisville	1968	
Calhoun			448.4
	Brussels	1974	
	Foley	1975	
	Hamburg	1978	
	Kampsville	1980	
St. Clair			241.6
	Cahokia	1974	
	Collinsville	1974	
	Columbia	1979	
	Freeburg	1974	
	French Village	1982	
	Mascoutah	1990	
Jersey			159.5
	Alton	1974	
	Brussels	1974	
	Elsah	1974	
	Grafton	1974	
	Hardin	1978	
	Nutwood	1975	

	Otterville	1983	
Pike			135.6
	Barry	1978	
	Pearl East	1980	
	Pearl West	1980	
	Summer Hill	1981	

Appendix A. Continued.

County	Quad	Quad year	Area ha[a]
Adams			132.3
	Lima	1981	
	Long Island	1981	
	Loraine	1981	
	Quincy East	1971	
	Quincy West	1971	
	Richfield	1981	
	Tioga	1981	
Macoupin			97.9
	Carlinville West	1979	
	Plainview	1974	
McHenry			90.7
	Hebron	1972	
	Fox Lake	1993	
	Marengo North	1970	
Will			85.0
	Joliet	1973	
Jefferson			83.8
	Harmony	1965	
	Irvington	1974	
	Kell	1978	
	Mount Vernon	1978	
	Walnut Hill	1974	
Marion			81.7
	Centralia East	1970	
	Harmony	1965	
	Irvington	1974	
	Iuka	1965	

	Kell	1978	
	Salem North	1978	
	Salem South	1978	
Lake			70.4
	Antioch	1993	
	Grayslake	1993	
	Libertyville	1993	
Madison			63.5
	Bethalto	1974	
	Collinsville	1974	
	Elsah	1974	
	Worden	1982	
Randolph			63.5
	Coulterville	1982	
	Kaskaskia	1982	
	Chester	1970	

Appendix A. Continued.

County	Quad	Quad year	Area ha[a]
Wayne			60.3
	Bluford	1973	
Rock Island			58.7
	Fort Byron	1991	
	Milan	1992	
	Silvis	1991	
Marshall			56.7
	Castleton	1983	
	La Prairie Center	1983	
Franklin			55.8
	Christopher	1968	
	Harco	1963	
	Johnston City	1976	
	Macedonia	1974	
	Pittsburg	1963	
	Rend Lake Dam	1975	
	Sesser	1975	
	Thompsonville	1976	
	West Frankfort	1978	

Winnebago			55.0
	Ridott	1971	
	South Beloit	1993	
Hancock			50.6
	Augusta	1981	
	Nauvoo	1975	
	Niota	1964	
	Tioga	1981	
Johnson			49.0
	Creal Springs	1976	
	Cypress	1966	
	Goreville	1990	
	Stonefort	1961	
Massac			48.6
	Metropolis	1990	

[a]U.S. Department of Commerce. 1994. 1992 Census of agriculture. Vol 1 Part 13. Illinois state and county data.

Appendix B. Accuracy assessment and error estimates[a] for Illinois counties classified from Landsat 5 TM satellite data.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Adams County								
Crop	21	4	0	0	25	16.0	28.0	84.0
Grass	7	21	0	0	28	25.0	17.9	75.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	1	0	13	14	7.1	0.0	92.9
Sum	28	26	21	13	88			
Overall Accuracy: 86% Kappa: 0.81								
Alexander County - no accuracy assessment								
Bond County - no accuracy assessment								
Boone County								
Crop	31	0	0	0	31	0.0	9.7	100.0
Grass	1	23	0	0	24	4.2	0.0	95.8
Woods	0	0	26	0	26	0.0	0.0	100.0
Water	2	0	0	7	9	22.2	0.0	77.8
Sum	34	23	26	7	90			
Overall Accuracy: 97% Kappa: 0.95								
Brown County								
Crop	24	2	0	0	26	7.7	19.2	92.3
Grass	5	18	0	0	23	21.7	8.7	78.3
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	10.0	100.0
Sum	29	20	23	10	82			
Overall Accuracy: 92% Kappa: 0.88								

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Bureau County								
Crop	37	0	1	0	38	2.6	21.1	97.4
Grass	8	18	0	0	26	30.8	0.0	69.2
Woods	0	0	16	0	16	0.0	6.3	100.0
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	45	18	17	9	89			
Overall Accuracy: 90% Kappa: 0.85								
Calhoun County - no accuracy assessment								
Carroll County								
Crop	16	1	0	0	17	5.9	5.9	94.1
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	1	16	0	17	5.9	0.0	94.1
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	17	20	16	6	59			
Overall Accuracy: 95% Kappa: 0.93								
Cass County								
Crop	30	1	0	0	31	3.2	16.1	96.8
Grass	5	14	0	0	19	26.3	5.3	73.7
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	35	15	17	11	78			
Overall Accuracy: 92% Kappa: 0.89								
Champaign County								
Crop	36	0	0	0	36	0.0	11.1	100.0
Grass	3	14	0	0	17	17.7	0.0	82.4
Woods	1	0	11	0	12	8.3	0.0	91.7
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	40	14	11	10	75			

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        Overall Accuracy: 95%     Kappa: 0.92
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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Christian County								
Crop	25	2	0	0	27	7.4	7.4	92.6
Grass	2	11	0	0	13	15.4	15.4	84.6
Woods	0	0	14	0	14	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	27	13	14	6	60			
	Overall Accuracy: 93%			Kappa: 0.90				
Clark County								
Crop	24	0	0	0	24	0.0	33.3	100.0
Grass	7	10	1	0	18	44.4	5.6	55.6
Woods	0	1	23	0	24	4.2	4.2	95.8
Water	1	0	0	8	9	11.1	0.0	88.9
Sum	32	11	24	8	75			
	Overall Accuracy: 87%			Kappa: 0.81				
Clay County								
Crop	23	1	0	0	24	4.2	25.0	95.8
Grass	6	9	0	0	15	40.0	13.3	60.0
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	0	1	0	6	7	14.3	0.0	85.7
Sum	29	11	15	6	61			
	Overall Accuracy: 87%			Kappa: 0.81				
Clinton County								
Crop	24	2	0	0	26	7.7	23.1	92.3
Grass	6	13	1	0	20	35.0	10.0	65.0
Woods	0	0	14	0	14	0.0	7.1	100.0
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	30	15	15	9	69			
	Overall Accuracy: 87%			Kappa: 0.82				

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Coles County								
Crop	28	0	0	0	28	0.0	21.4	100.0
Grass	6	10	0	0	16	37.5	0.0	62.5
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	34	10	13	11	68			
Overall Accuracy: 91% Kappa: 0.87								
Cook County - no accuracy assessment								
Crawford County								
Crop	19	2	1	0	22	13.6	13.6	86.4
Grass	3	7	0	0	10	30.0	20.0	70.0
Woods	0	0	21	0	21	0.0	4.8	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	22	9	22	8	61			
Overall Accuracy: 90% Kappa: 0.86								
Cumberland County								
Crop	29	0	0	0	29	0.0	6.9	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	31	14	22	6	73			
Overall Accuracy: 97% Kappa: 0.96								
De Kalb County								
Crop	32	0	0	0	32	0.0	6.3	100.0
Grass	2	10	0	0	12	16.7	0.0	83.3
Woods	0	0	0	0	0	-	-	-
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	34	10	0	6	50			

Overall Accuracy: 96% Kappa: 0.92

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
De Witt County								
Crop	33	0	0	0	33	0.0	24.2	100.0
Grass	4	13	0	0	17	23.5	5.9	76.5
Woods	4	1	8	0	13	38.5	0.0	61.5
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	41	14	8	7	70			
Overall Accuracy: 87% Kappa: 0.80								
Douglas County								
Crop	32	1	0	0	33	3.0	27.3	97.0
Grass	9	7	0	0	16	56.3	6.3	43.8
Woods	0	0	12	0	12	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	41	8	12	5	66			
Overall Accuracy: 85% Kappa: 0.76								
Du Page County - no accuracy assessment								
Edgar County								
Crop	29	1	0	0	30	3.3	3.3	96.7
Grass	1	21	0	0	22	4.5	9.1	95.5
Woods	0	1	7	0	8	12.5	0.0	87.5
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	30	23	7	7	67			
Overall Accuracy: 96% Kappa: 0.93								
Edwards County								
Crop	23	1	0	0	24	4.2	16.7	95.8
Grass	3	18	0	0	21	14.3	4.8	85.7
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	1	0	0	11	12	8.3	0.0	91.7

Sum	27	19	22	11	79

Overall Accuracy: 94% Kappa: 0.91

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Effingham County								
Crop	22	1	0	0	23	4.3	30.4	95.7
Grass	6	11	0	0	17	35.3	11.8	64.7
Woods	1	0	14	0	15	6.7	0.0	93.3
Water	0	1	0	7	8	12.5	0.0	87.5
Sum	29	13	14	7	63			
Overall Accuracy: 86% Kappa: 0.80								
Fayette County								
Crop	22	0	0	0	22	0.0	22.7	100.0
Grass	5	15	0	0	20	25.0	0.0	75.0
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	27	15	19	7	68			
Overall Accuracy: 93% Kappa: 0.90								
Ford County								
Crop	40	0	0	0	40	0.0	5.0	100.0
Grass	2	19	0	0	21	9.5	0.0	90.5
Woods	0	0	9	0	9	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	42	19	9	7	77			
Overall Accuracy: 97% Kappa: 0.96								
Franklin County								
Crop	25	2	0	0	27	7.4	11.1	92.6
Grass	2	15	0	0	17	11.8	11.8	88.2
Woods	1	0	18	0	19	5.3	0.0	94.7
Water	0	0	0	7	7	0.0	0.0	100.0

```
Sum         28     17      18       7     70

        Overall Accuracy: 93%     Kappa: 0.90
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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Fulton County								
Crop	24	0	0	0	24	0.0	37.5	100.0
Grass	9	11	0	0	20	45.0	15.0	55.0
Woods	0	2	17	0	19	10.5	5.3	89.5
Water	0	1	1	10	12	16.7	0.0	83.3
Sum	33	14	18	10	75			
Overall Accuracy: 83% Kappa: 0.76								
Gallatin County								
Crop	16	0	0	0	16	0.0	18.8	100.0
Grass	3	19	0	0	22	13.6	0.0	86.4
Woods	0	0	18	0	18	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	19	19	18	7	63			
Overall Accuracy: 95% Kappa: 0.93								
Greene County - no accuracy assessment								
Grundy County								
Crop	28	2	0	0	30	6.7	3.3	93.3
Grass	1	9	0	0	10	10.0	20.0	90.0
Woods	0	0	14	0	14	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	11	14	6	60			
Overall Accuracy: 95% Kappa: 0.92								
Hamilton County								
Crop	16	2	0	0	18	11.1	0.0	88.9
Grass	0	25	0	0	25	0.0	8.0	100.0
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	13	13	0.0	0.0	100.0
Sum	16	27	20	13	76			

Overall Accuracy: 97% Kappa: 0.96

Appendix B. Continued.

Land Use Class[b]	Classified Map Crop	Grass	Woods	Water	Sum	Error(%) Omission	Commission	Accuracy (%)
Hancock County								
Crop	17	0	0	0	17	0.0	5.9	100.0
Grass	1	22	0	0	23	4.3	13.0	95.7
Woods	0	0	9	0	9	0.0	0.0	100.0
Water	0	3	0	1	4	75.0	0.0	25.0
Sum	18	25	9	1	53			
Overall Accuracy: 92% Kappa: 0.88								
Hardin County								
Crop	16	0	0	0	16	0.0	18.8	100.0
Grass	3	19	0	0	22	13.6	0.0	86.4
Woods	0	0	18	0	18	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	19	19	18	7	63			
Overall Accuracy: 95% Kappa: 0.93								
Henderson County								
Crop	21	0	0	0	21	0.0	38.1	100.0
Grass	8	7	0	0	15	53.3	0.0	46.7
Woods	0	0	17	0	17	0.0	5.9	100.0
Water	0	0	1	2	3	33.3	0.0	66.7
Sum	29	7	18	2	56			
Overall Accuracy: 84% Kappa: 0.76								
Henry County								
Crop	38	0	0	0	38	0.0	5.3	100.0
Grass	2	15	0	0	17	11.8	0.0	88.2
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0

Sum	40	15	17	5	77

Overall Accuracy: 97% Kappa: 0.96

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Iroquois County								
Crop	31	0	1	0	32	3.1	6.3	96.9
Grass	2	9	0	0	11	18.2	0.0	81.8
Woods	0	0	9	0	9	0.0	11.1	100.0
Water	0	0	0	4	4	0.0	0.0	100.0
Sum	33	9	10	4	56			

Overall Accuracy: 95% Kappa: 0.91

Jackson County								
Crop	22	0	0	0	22	0.0	18.2	100.0
Grass	4	17	0	0	21	19.0	0.0	81.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	26	17	21	11	75			

Overall Accuracy: 95% Kappa: 0.93

Jasper County								
Crop	23	1	0	0	24	4.2	25.0	95.8
Grass	6	9	0	0	15	40.0	13.3	60.0
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	0	1	0	6	7	14.3	0.0	85.7
Sum	29	11	15	6	61			

Overall Accuracy: 87% Kappa: 0.81

Jefferson County								
Crop	22	1	0	0	23	4.3	39.1	95.7
Grass	9	12	0	0	21	42.9	4.8	57.1

Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	31	13	20	11	75			

Overall Accuracy: 87% Kappa: 0.82

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Jersey County								
Crop	31	0	0	0	31	0.0	9.7	100.0
Grass	3	14	0	0	17	17.6	0.0	82.4
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	34	14	22	8	78			
Overall Accuracy: 96% Kappa: 0.94								
Jo Daviess County								
Crop	16	1	0	0	17	5.9	5.9	94.1
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	1	16	0	17	5.9	0.0	94.1
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	17	20	16	6	59			
Overall Accuracy: 95% Kappa: 0.93								
Johnson County								
Crop	7	1	0	0	8	12.5	25.0	87.5
Grass	2	21	0	0	23	8.7	4.3	91.3
Woods	0	0	25	0	25	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	9	22	25	8	64			
Overall Accuracy: 95% Kappa: 0.93								
Kane County								
Crop	26	0	0	0	26	0.0	11.5	100.0

Grass	3	12	0	0	15	20.0	0.0	80.0
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	12	13	6	60			

Overall Accuracy: 95% Kappa: 0.93

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Kankakee County								
Crop	34	0	0	0	34	0.0	11.8	100.0
Grass	4	12	0	0	16	25.0	0.0	75.0
Woods	0	0	0	0	0	-	-	-
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	38	12	0	6	56			

Overall Accuracy: 93% Kappa: 0.86

Kendall County

Crop	32	0	1	0	33	3.0	39.4	97.0
Grass	12	2	0	0	14	85.7	0.0	14.3
Woods	1	0	8	0	9	11.1	11.1	88.9
Water	0	0	0	4	4	0.0	0.0	100.0
Sum	45	2	9	4	60			

Overall Accuracy: 77% Kappa: 0.58

Knox County - no accuracy assessment

Lake County - no accuracy assessment

La Salle County

Crop	26	0	0	0	26	0.0	30.8	100.0
Grass	8	14	0	0	22	36.4	0.0	63.6
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	34	14	13	7	68			

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        Overall Accuracy: 88%     Kappa: 0.83
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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Lawrence County								
Crop	22	0	0	0	22	0.0	18.2	100.0
Grass	2	15	1	0	18	16.7	5.6	83.3
Woods	0	1	19	0	20	5.0	10.0	95.0
Water	2	0	1	3	6	50.0	0.0	50.0
Sum	26	16	21	3	66			
Overall Accuracy: 89% Kappa: 0.85								
Lee County								
Crop	34	0	0	0	34	0.0	11.8	100.0
Grass	4	11	0	0	15	26.7	0.0	73.3
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	38	11	22	12	83			
Overall Accuracy: 95% Kappa: 0.93								
Livingston County								
Crop	31	0	0	0	31	0.0	12.9	100.0
Grass	4	11	0	0	15	26.7	0.0	73.3
Woods	0	0	7	0	7	0.0	0.0	100.0
Water	0	0	0	3	3	0.0	0.0	100.0
Sum	35	11	7	3	56			
Overall Accuracy: 93% Kappa: 0.88								
Logan County								
Crop	35	0	0	0	35	0.0	8.6	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	15	0	15	0.0	0.0	100.0
Water	1	0	0	7	8	12.5	0.0	87.5
Sum	38	14	15	7	74			
Overall Accuracy: 96% Kappa: 0.94								

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Macon County								
Crop	28	0	0	0	28	0.0	3.6	100.0
Grass	1	9	0	0	10	10.0	0.0	90.0
Woods	0	0	6	0	6	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	29	9	6	6	50			
Overall Accuracy: 98% Kappa: 0.97								
Macoupin County								
Crop	23	1	0	0	24	4.2	12.5	95.8
Grass	3	17	0	0	20	15.0	5.0	85.0
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	26	18	19	7	70			
Overall Accuracy: 94% Kappa: 0.92								
Madison County								
Crop	29	3	0	0	32	9.4	9.4	90.6
Grass	3	13	0	0	16	18.8	25.0	81.3
Woods	0	1	14	0	15	6.7	0.0	93.3
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	32	17	14	12	75			
Overall Accuracy: 91% Kappa: 0.87								
Marion County								
Crop	21	1	0	0	22	4.5	27.3	95.5
Grass	6	12	0	0	18	33.3	5.6	66.7
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	27	13	20	12	72			
Overall Accuracy: 90% Kappa: 0.87								

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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Marshall County								
Crop	33	0	0	0	33	0.0	6.1	100.0
Grass	2	8	0	0	10	20.0	0.0	80.0
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	35	8	8	5	56			
	Overall Accuracy: 96%			Kappa: 0.94				
Mason County								
Crop	30	1	0	0	31	3.2	45.2	96.8
Grass	14	5	0	0	19	73.7	5.3	26.3
Woods	0	0	16	0	16	0.0	6.3	100.0
Water	0	0	1	12	13	7.7	0.0	92.3
Sum	44	6	17	12	79			
	Overall Accuracy: 80%			Kappa: 0.71				
Massac County								
Crop	24	0	0	0	24	0.0	16.7	100.0
Grass	4	24	0	0	28	14.3	0.0	85.7
Woods	0	0	30	0	30	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	28	24	30	6	88			
	Overall Accuracy: 96%			Kappa: 0.94				
McDonough County								
Crop	24	0	0	0	24	0.0	37.5	100.0
Grass	9	11	0	0	20	45.0	15.0	55.0
Woods	0	2	17	0	19	10.5	5.3	89.5
Water	0	1	1	10	12	16.7	0.0	83.3
Sum	33	14	18	10	75			
	Overall Accuracy: 83%			Kappa: 0.76				

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Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
McHenry County - no accuracy assessment								
McLean County - no accuracy assessment								
Menard County - no accuracy assessment								
Mercer County - no accuracy assessment								
Monroe County								
Crop	20	1	0	0	21	4.8	33.3	95.2
Grass	7	12	0	0	19	36.8	5.3	63.2
Woods	0	0	17	0	17	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	27	13	17	12	69			
Overall Accuracy: 88% Kappa: 0.84								
Montgomery County								
Crop	16	1	0	0	17	5.9	23.5	94.1
Grass	4	9	0	0	13	30.8	15.4	69.2
Woods	0	1	15	0	16	6.3	0.0	93.7
Water	0	0	0	9	9	0.0	0.0	100.0
Sum	20	11	15	9	55			
Overall Accuracy: 89% Kappa: 0.85								
Morgan County								
Crop	27	1	0	0	28	3.6	14.3	96.4
Grass	4	13	0	0	17	23.5	5.9	76.5
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	31	14	20	10	75			
Overall Accuracy: 93% Kappa: 0.91								

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Moultrie County - no accuracy assessment								
Ogle County								
Crop	23	0	0	0	23	0.0	17.4	100.0
Grass	2	20	2	0	24	16.7	4.2	83.3
Woods	0	1	14	0	15	6.7	13.3	93.3
Water	2	0	0	7	9	22.2	0.0	77.8
Sum	27	21	16	7	71			
Overall Accuracy: 90% Kappa: 0.86								
Peoria County								
Crop	25	0	0	0	25	0.0	4.0	100.0
Grass	1	10	0	0	11	9.1	0.0	90.9
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	26	10	13	11	60			
Overall Accuracy: 98% Kappa: 0.98								
Perry County								
Crop	24	1	0	0	25	4.0	12.0	96.0
Grass	3	15	0	0	18	16.7	5.6	83.3
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	16	16	0.0	0.0	100.0
Sum	27	16	20	16	79			
Overall Accuracy: 95% Kappa: 0.93								
Piatt County								
Crop	29	0	0	0	29	0.0	6.9	100.0
Grass	2	21	0	0	23	8.7	0.0	91.3
Woods	0	0	10	0	10	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	31	21	10	8	70			

Overall Accuracy: 97% Kappa: 0.96

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Pike County								
Crop	24	1	0	0	25	4.0	8.0	96.0
Grass	2	19	0	0	21	9.5	4.8	90.5
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	26	20	23	8	77			
Overall Accuracy: 96% Kappa: 0.95								
Pope County								
Crop	7	1	0	0	8	12.5	25.0	87.5
Grass	2	21	0	0	23	8.7	4.3	91.3
Woods	0	0	25	0	25	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	9	22	25	8	64			
Overall Accuracy: 95% Kappa: 0.93								
Pulaski County								
Crop	23	0	1	0	24	4.2	4.2	95.8
Grass	1	17	0	0	18	5.6	5.6	94.4
Woods	0	1	17	0	18	5.6	5.6	94.4
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	24	18	18	11	71			
Overall Accuracy: 96% Kappa: 0.94								
Putnam County								
Crop	33	0	0	0	33	0.0	6.1	100.0
Grass	2	8	0	0	10	20.0	0.0	80.0
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	35	8	8	5	56			

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        Overall Accuracy: 96%     Kappa: 0.94
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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Randolph County								
Crop	23	1	0	0	24	4.2	8.3	95.8
Grass	2	16	0	0	18	11.1	11.1	88.9
Woods	0	1	21	0	22	4.5	0.0	95.5
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	25	18	21	11	75			
	Overall Accuracy: 95%			Kappa: 0.93				
Richland County								
Crop	24	1	0	0	25	4.0	20.0	96.0
Grass	5	11	0	0	16	31.2	6.3	68.8
Woods	0	0	22	0	22	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	29	12	22	10	73			
	Overall Accuracy: 92%			Kappa: 0.89				
Rock Island County								
Crop	30	1	0	0	31	3.2	9.7	96.8
Grass	3	18	0	0	21	14.3	4.8	85.7
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	33	19	16	7	75			
	Overall Accuracy: 95%			Kappa: 0.92				
Saline County								
Crop	20	0	0	0	20	0.0	50.0	100.0
Grass	10	10	0	1	21	52.4	0.0	47.6
Woods	0	0	19	0	19	0.0	0.0	100.0
Water	0	0	0	15	15	0.0	6.7	100.0
Sum	30	10	19	16	75			
	Overall Accuracy: 85%			Kappa: 0.80				

Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Sangamon County								
Crop	40	1	0	0	41	2.4	2.4	97.6
Grass	1	16	0	0	17	5.9	17.6	94.1
Woods	0	2	16	0	18	11.1	0.0	88.9
Water	0	0	0	13	13	0.0	0.0	100.0
Sum	41	19	16	13	89			
	Overall Accuracy: 96%			Kappa: 0.93				
Schuyler County								
Crop	23	5	0	0	28	17.9	7.1	82.1
Grass	2	11	0	0	13	15.4	38.5	84.6
Woods	0	0	20	0	20	0.0	0.0	100.0
Water	0	0	0	11	11	0.0	0.0	100.0
Sum	25	16	20	11	72			
	Overall Accuracy: 90%			Kappa: 0.87				
Scott County								
Crop	23	2	0	0	25	8.0	4.0	92.0
Grass	1	18	0	0	19	5.3	10.5	94.7
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	24	20	21	8	73			
	Overall Accuracy: 96%			Kappa: 0.94				
Shelby County								
Crop	24	0	0	0	24	0.0	25.0	100.0
Grass	6	13	0	0	19	31.6	10.5	68.4
Woods	0	2	18	0	20	10.0	0.0	90.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	30	15	18	6	69			
	Overall Accuracy: 88%			Kappa: 0.84				

Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Stark County - no accuracy assessment								
St. Clair County								
Crop	25	0	0	0	25	0.0	12.0	100.0
Grass	3	13	0	0	16	18.8	0.0	81.2
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	28	13	13	6	60			
Overall Accuracy: 95% Kappa: 0.93								
Stephenson County								
Crop	31	0	1	0	32	3.1	31.3	96.9
Grass	10	15	0	0	25	40.0	0.0	60.0
Woods	0	0	23	0	23	0.0	4.3	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	41	15	24	8	88			
Overall Accuracy: 88% Kappa: 0.82								
Tazewell County								
Crop	34	0	0	0	34	0.0	8.8	100.0
Grass	3	17	0	0	20	15.0	0.0	85.0
Woods	0	0	11	0	11	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	37	17	11	5	70			
Overall Accuracy: 96% Kappa: 0.93								
Union County								
Crop	16	3	0	0	19	15.8	10.5	84.2
Grass	2	11	0	0	13	15.4	23.1	84.6
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	12	12	0.0	0.0	100.0
Sum	18	14	16	12	60			

Overall Accuracy: 92% Kappa: 0.89

Appendix B. Continued.

Land Use Class[b]	Classified Map Crop	Grass	Woods	Water	Sum	Error(%) Omission	Commission	Accuracy (%)
Vermilion County								
Crop	35	0	0	0	35	0.0	5.7	100.0
Grass	2	14	0	0	16	12.5	0.0	87.5
Woods	0	0	8	0	8	0.0	0.0	100.0
Water	0	0	0	6	6	0.0	0.0	100.0
Sum	37	14	8	6	65			
Overall Accuracy: 97% Kappa: 0.95								
Wabash County								
Crop	26	0	0	0	26	0.0	19.2	100.0
Grass	5	11	0	0	16	31.3	0.0	68.7
Woods	0	0	16	0	16	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	31	11	16	10	68			
Overall Accuracy: 93% Kappa: 0.90								
Warren County								
Crop	19	0	0	0	19	0.0	36.8	100.0
Grass	6	10	0	0	16	37.5	0.0	62.5
Woods	1	0	14	0	15	6.7	0.0	93.3
Water	0	0	0	3	3	0.0	0.0	100.0
Sum	26	10	14	3	53			
Overall Accuracy: 87% Kappa: 0.81								
Washington County								
Crop	24	1	0	0	25	4.0	28.0	96.0
Grass	6	14	0	0	20	30.0	5.0	70.0
Woods	0	0	21	0	21	0.0	0.0	100.0
Water	1	0	0	11	12	8.3	0.0	91.7
Sum	31	15	21	11	78			

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        Overall Accuracy: 90%     Kappa: 0.86
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Appendix B. Continued.

Land Use Class[b]	Classified Map: Crop	Grass	Woods	Water	Sum	Error(%): Omission	Commission	Accuracy (%)
Wayne County								
Crop	19	2	1	0	22	13.6	45.5	86.4
Grass	10	9	2	0	21	57.1	9.5	42.9
Woods	0	0	20	0	20	0.0	15.0	100.0
Water	0	0	0	16	16	0.0	0.0	100.0
Sum	29	11	23	16	79			
Overall Accuracy: 81%				Kappa: 0.75				
White County								
Crop	15	2	0	0	17	11.8	29.4	88.2
Grass	5	7	0	0	12	41.7	16.7	58.3
Woods	0	0	13	0	13	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	20	9	13	5	47			
Overall Accuracy: 85%				Kappa: 0.79				
Whiteside County								
Crop	25	1	0	0	26	3.8	19.2	96.2
Grass	5	14	0	0	19	26.3	10.5	73.7
Woods	0	1	18	0	19	5.3	0.0	94.7
Water	0	0	0	1	1	0.0	0.0	100.0
Sum	30	16	18	1	65			
Overall Accuracy: 89%				Kappa: 0.84				
Will County								
Crop	22	3	0	0	25	12.0	0.0	88.0
Grass	0	10	0	0	10	0.0	30.0	100.0
Woods	0	0	10	0	10	0.0	0.0	100.0
Water	0	0	0	5	5	0.0	0.0	100.0
Sum	22	13	10	5	50			
Overall Accuracy: 94%				Kappa: 0.91				

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Appendix B. Continued.

Land Use Class[b]	Classified Map					Error(%)		Accuracy (%)
	Crop	Grass	Woods	Water	Sum	Omission	Commission	
Williamson County								
Crop	19	3	0	0	22	13.6	27.3	86.4
Grass	6	19	0	0	25	24.0	12.0	76.0
Woods	0	0	23	0	23	0.0	0.0	100.0
Water	0	0	0	10	10	0.0	0.0	100.0
Sum	25	22	23	10	80			
Overall Accuracy: 89% Kappa: 0.85								
Winnebago County								
Crop	31	0	1	0	32	3.1	31.3	96.9
Grass	10	15	0	0	25	40.0	0.0	60.0
Woods	0	0	23	0	23	0.0	4.3	100.0
Water	0	0	0	8	8	0.0	0.0	100.0
Sum	41	15	24	8	88			
Overall Accuracy: 88% Kappa: 0.82								
Woodford County								
Crop	41	0	1	0	42	2.4	2.4	97.6
Grass	1	11	0	0	12	8.3	0.0	91.7
Woods	0	0	9	0	9	0.0	11.1	100.0
Water	0	0	0	7	7	0.0	0.0	100.0
Sum	42	11	10	7	70			
Overall Accuracy: 97% Kappa: 0.95								

[a]Calculated according to Congalton 1991.

[b]Ground truth data from Illinois Department of Natural Resources quail and pheasant call count routes.

Job 1.2: **Development of habitat Models**

Objectives: (1) To develop and refine habitat-based models that exploit classified remote sensing data bases; (2) to develop and refine computer algorithms to quantify important landscape characteristics and identify critical or threatened habitat components.

INTRODUCTION

In addressing objective 1, the original intent was to develop a series of species-specific habitat models of the Habitat Suitability Index (HSI) type (e.g., Roseberry and Richards 1992). However, we subsequently decided that Pattern Recognition (PATREC) models (Williams et al. 1977, Grubb 1988) would be more appropriate than HSI type models for incorporation into the interactive workstation software (Job 1.3). This decision was based on several factors. PATREC models require less-specific assumptions regarding functional relationships between habitat components and species' life requisites and thus may be more appropriate for use with relatively coarse-grained classified satellite imagery (Aspinall and Veitch 1993, Gustafson et al. 1994). Secondly, PATREC models are sufficiently general

to be useful at different spatial scales and levels of classification. Finally, their relatively simple and uniform structure make them amenable to on-screen development, testing, and modification. By incorporating a graphical user interface (GUI) into the habitat analysis program, users can construct and store their own PATREC models for any desired species or community. Models can be tailored to fit the spatial and contextual resolution of the classified image. Models also can include user-defined variables thus permitting incorporation of explicit information not available from the classified image. These capabilities should greatly expand the utility and flexibility of the software package.

METHODS

The acquisition of several computer packages containing algorithms for quantifying landscape composition and spatial attributes (e.g., Baker and Cai 1992, Gustafson and Parker 1992, McGarigal and Marks 1994) facilitated completion of objective 2. The following metrics were selected from these and other sources and modified as necessary for inclusion into the graphics display program (Job 1.3):

Proportion.--The proportional representation of each land cover type (classes).

Contagion.--An index of the extent to which classes are aggregated or clumped (Li and Reynolds 1993:159, McGarigal and Marks 1994:57).

Dominance.--An index of the degree to which one or a few classes dominate the landscape (O'Neill et al. 1988:154).

Diversity.--An index of the richness and evenness of the landscape (McGarigal and Marks 1994:54).

Class Richness.--The number of different classes per unit area.

Relative Class Richness.--The number of different classes expressed as a percentage of the total number of classes in the landscape.

Shared Edge Distance.--The total number of pixel adjacencies among all combinations of classes.

Interspersion.--A ratio of the total number of connections between pixels of different classes divided by the maximum possible number of connections (Heinen and Cross 1983).

Juxtaposition.--The same as interspersion except that connections between various class combinations are weighted from zero to one to reflect relative importance.

Number of Patches.--The total number of patches of a given class expressed absolutely or per unit area.

Mean Patch Size.--The average size of all patches of a given class.

Total Perimeter.--The number of outermost pixels in each patch of a given class summed over all patches of that class.

Distance to Nearest Neighbor.--The distance from each individual patch of a given class to the nearest patch of the same class.

Distance to Nearest Complimentary Type.--The distance from each individual patch of a given class to the nearest patch of a designated complimentary class.

Neighbor Distance in Proximity Zone.--The mean distance from each individual patch to all of the patches of the same class located within a specified proximity zone of the focal patch.

Proximity Index.--This index measures the relative isolation of patches and is a function of the size and distance between patches in a designated zone (Gustafson and Parker 1992, McGarigal and Marks 1994).

Fractal Dimension.--A measure of the complexity of the shape of individual patches (Krummel et al. 1987, O'Neill et al. 1988).

Modified Fractal Dimension.--An index of landscape diversity that incorporates patch shape, patch juxtaposition, richness, and evenness (Olsen et al. 1993).

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Job 1.3: **Incorporate the products from Jobs 1.1 and 1.2 into an interactive, management-oriented computer workstation**

Objective: To develop a computerized workstation that will enable district level resource managers to access and utilize remotely sensed, classified land use/habitat information.

INTRODUCTION

The ability to inventory, quantify, and evaluate habitat at various spatial scales is essential for effective wildlife management. Traditional perspectives of habitat are broadening to address concerns about biodiversity, fragmentation, and ecosystem management (Dunning et al. 1992). This shift in focus from smaller to larger scales has coincided with, and been facilitated by, advances in remote sensing, Geographical Information Systems (GIS), and methods for quantifying spatial attributes of landscapes. Land use/land cover can now be inventoried and classified over large geographic areas using satellite imagery (Lillesand and Kiefer 1987). Landscape composition and pattern can be described by a variety of metrics (e.g., O'Neill et al. 1988, McGarigal and Marks 1994, Riitters et

al. 1995), and habitat suitability can be assessed with various types of models (Verner et al. 1984). Realistically, however, many wildlife managers still have limited access to these powerful tools because of restrictive requirements for specialized computer hardware, software, and expertise.

METHODS

HAMS is written in the Borland® C++ 4.0 programming language. The program runs on IBM/AT-compatible microcomputers with i386 or above processors and at least 8 MB RAM (16 or more recommended). A 14" color VGA monitor is required (17" color SVGA recommended). Operating system requirements are MS-DOS® Version 5.0 or later and MS-Windows™ Version 3.1 or later.

RESULTS AND DISCUSSION

The objective of Job 1.3 was to develop a PC-based computer program that combined graphical, analytical, and modeling capabilities into an easy-to-use system available to wildlife managers and resource planners lacking access to, or expertise with, more expensive and sophisticated GIS hardware and software. This objective was accomplished through the development of the Habitat Analysis and Modeling System (HAMS), an interactive,

Windows™ application program. This software enables users to graphically display, measure, modify, and analyze the composition and spatial structure of digitized land cover maps, and evaluate their suitability as habitat for selected wildlife species or communities.

HAMS accepts raster-format (grid cell) land use/land cover maps of $\leq$12 classes. Depending upon available memory, images up to approximately 2,400 x 2,400 rows and columns can be graphically displayed. Images can be selected from existing files or they can be created using on-screen edit tools and dialog boxes. Smaller study areas then can be defined for detailed analysis. Displayed images can be permanently edited or temporarily modified with the mouse to simulate land use/land cover changes or management alternatives. Land cover types (classes) can be added, deleted, or combined. Changes can be made globally to entire classes, or they can be limited to individual patches within the landscape. Features also can be added to or deleted from the landscape using rectangle, polygon, or linear draw tools.

Areal measurements can be taken of individual patches, entire classes, or user-drawn rectangles or polygons. Linear

distances between any 2 points on the image also can be measured. Results are reportable in various English or metric units.

Landscape structure (composition and spatial patterns) of displayed images can be quantified using selected metrics applicable to the entire landscape or individual classes. Landscape metrics currently available include class proportions, contagion, dominance, diversity, class richness, relative class richness, juxtaposition, interspersion, and shared edge among all combinations of classes. Patch characteristics may be computed for individual classes or the entire landscape. Available metrics include number of individual patches, mean patch size, total perimeter, several nearest neighbor metrics (McGarigal and Marks 1994, Gustafson and Parker 1992), mean fractal dimension, and mean modified fractal dimension (Olsen et al. 1993). Certain patch metrics can be expressed in absolute terms or per unit area. Nearest neighbor distances can also be computed for designated pairs of complimentary classes (e.g., woods/cropland). Discretionary buffer zones may be established around study areas to accommodate patches that extend beyond study area boundaries, and also to allow habitat patches in the immediate vicinity of the study area to be included in nearest neighbor metrics. If desired, original pixels can be "resampled" or aggregated into

larger pixels prior to calculation of patch metrics. Also, classes representing the landscape matrix (Forman and Godron 1986) can be so designated and thus excluded from patch calculations.

HAMS uses Pattern Recognition (PATREC) models (Williams et al. 1977) to evaluate habitat suitability of original or modified landscapes. Species or community-specific PATREC models can be selected from previously-saved files, or they can be created during a HAMS session using special dialog boxes. In addition to metrics computed from the displayed image, models can include user-defined variables, thus permitting incorporation of explicit information not available from the classified image. Completed models can be saved for future use. Models created in a text editor also can be used by HAMS.

Products from this job include a HAMS installation disk and a User's Guide and Reference Manual (Roseberry and Hao 1995) a photocopy of which is appended to this report. The installation disk includes a readme file, an installation program, the HAMS executable program, an example 200 x 250 image file and an example PATREC model.

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STUDY NO. 2: **Upland Wildlife Population Trends and Habitat Conditions**

Job 2.1: **Analyze bobwhite population trends**

Objective: To increase understanding and improve predictability of short- and long-term fluctuations and trends in bobwhite abundance as an aid to establishing harvest regulations and long-term planning.

INTRODUCTION

Nationwide population trends of northern bobwhite (Colinus virginianus) have been reported recently by several investigators. Brennan (1991) analyzed Christmas Bird Count data from 1961 through 1988 and found declines in 24 of 31 states in the bobwhite's primary range including Illinois. Church et al. (1993) examined North American Breeding Bird Survey data and reported declines from 1966 to 1991 in 22 of 28 states including Illinois. Sixteen of 26 states declined from 1982 to 1991 but bobwhite populations in Illinois were relatively stable. Previous analyses of hunter harvest surveys and male bobwhite call counts in Illinois generally corroborate these findings (Roseberry 1993, Roseberry and David 1994).

Long-term bobwhite population records are often characterized by temporary fluctuations in abundance superimposed over long-term trends (Roseberry and Klimstra 1984:121). Periodic oscillations are related primarily to weather and possibly a cyclic component (Roseberry and Klimstra 1984:155-157). The prevailing level about which the oscillations occur (i.e., the long-term trend) is thought to mainly reflect habitat conditions (Brennan 1991). The ability to identify and distinguish between long-term trends and short-term fluctuations and to predict the latter is essential for effective management of upland wildlife species in Illinois.

STUDY AREAS

For purposes of analysis and data presentation, Illinois was divided into 4 regions: south, southcentral, westcentral, and northeast (Fig. 1). Criteria and rational for this division were based on prevailing climate, land cover patterns, and estimated bobwhite densities (Roseberry and David 1994:62).

METHODS

Data Collection

Four indices of annual bobwhite abundance were used in this study: (1) estimated annual hunter harvest per square mile (KPA), (2) estimated number of quail harvested per hunter trip (KPT), (3) time/area counts of male bobwhite calls in early summer (MBC), and (4) the North American Breeding Bird Survey (BBS). Hunter harvest data for the period 1967-1993 were obtained by the Illinois Department of Natural Resources (IDNR) from post-season questionnaires mailed to a random sample of resident hunting license holders (Anderson and Campbell 1993:1-2). Male bobwhite call counts for the period 1975-1993 were systematically recorded by IDNR biologists along 46 semi-permanent routes (Roseberry and David 1994:62). Routes are 32 km in length and consist of 19-20 stops at 1.6-km intervals. Each transect is driven once per year in June by IDNR personnel and the number of male bobwhite calls recorded during a 2-minute listening period at each stop. The North American Breeding Bird Survey is conducted by the U.S. Fish and Wildlife Service and consists of 39.4-km routes along secondary roads each with 50 evenly spaced stops (Robbins et al. 1986). Volunteer observers count all individuals of every bird species seen or heard during a 3-minute interval at each stop. Only BBS routes located in the 3 major quail regions of Illinois were used for this report

(average 29 per year; range 10-36). Two variables were computed from these data: the mean number of individual bobwhites recorded per route per year (BBS) and a transformed annual value (TBS) designed to eliminate observer effects (Geissler and Sauer 1990, Sauer and Geissler 1990). The latter index was computed for the Illinois data by John Sauer of the U.S. Fish and Wildlife Service.

Weather data were obtained from approximately 50 weather stations in Illinois for the period 1950-1993. The procedure for deriving annual weather variables was as follows: daily maximum and minimum temperatures and precipitation for each year and weather station were read from Illinois Climatological Data (U.S. Dep. Commerce 1953-1993) and entered into ASCII computer files. These data files were then input into a FORTRAN computer program that calculated average maximum, minimum, and mean daily temperatures, total precipitation, potential evapotranspiration (Thornthwaite 1948, Thornthwaite and Mather 1957), and a drought index (Palmer 1965) for each of the 12 calendar months plus 11 additional biological periods in the bobwhite's annual cycle. An additional variable, total number of days of snow cover ≥2.54 cm (SNO) also was obtained from all weather stations recording such information. Individual weather station data then were combined

in another FORTRAN program to compute regional and statewide means for each of the variables.

Also included in the weather dataset was a variable indexing a potential temporal bobwhite population cycle (Roseberry and Klimstra 1984). This variable quantified the nodal lunar cycle (CYC) and was computed from information in the Nautical Almanac (1973-93) using methods described by Archibald (1977).

Statistical Analyses

Simple correlation analysis (PROC CORR) was used to determine the intercorrelation among population indices and between these indices and weather variables. Following initial filtering of weather variables, multiple linear regression (PROC REG) was used to develop predictive equations for KPT and KPA (SAS Institute Inc. 1985). Because prediction was the primary objective, a liberal P of about 0.20 was used for inclusion of variables into the equations.

An attempt was made to assess the representativeness of individual male call count routes with regard to their respective regions. This was done by comparing annual MBC from each route with its respective regional mean MBC (minus the route being tested) using simple correlation analysis. Similarly, the

predictive ability of each route was evaluated by correlating its annual MBC with corresponding regional KPT and KPA values (including the route being tested). Ignoring statistical significance because of small sample sizes, 4 categories of relationships were defined: strong ($r \geq +0.70$), medium ($r = +0.50 - 0.69$), weak ($r = +0.30 - 0.49$), and none ($r < +0.30$).

RESULTS AND DISCUSSION

Catch per unit effort indices (e.g., KPT) reflect pre-catch population size in various species (Caughley 1977) including northern bobwhite (Vance and Ellis 1972, Roseberry and Klimstra 1984). Estimates of total annual harvest (e.g., KPA) also correlate positively with local prehunt bobwhite densities (Vance and Ellis 1972, Snyder 1978, Roseberry and Klimstra 1984). The relationship between male bobwhite whistling counts (e.g., MBC) and subsequent fall abundance is more questionable, with variable results reported in the literature (see reviews by Roseberry and Klimstra 1984:103 and Curtis et al. 1989:253-254). Because of the systematic nature of the North American Breeding Bird Survey, Church et al. (1993) considered them useful for monitoring bobwhite population trends on a national scale. To our knowledge, there have been few, if any, attempts to compare BBS

and state harvest survey results for bobwhite prior to the present study.

There was general agreement among the various population indices in terms of short-term annual fluctuations (Table 1). The BBS results were strongly and significantly ($P < 0.001$) correlated with both KPT ($r = +0.90$) and KPA ($r = +0.89$); the latter 2 variables were also highly correlated ($r = +0.84$; $P < 0.001$). Interestingly, the untransformed or "raw" BBS results correlated more closely with KPT, KPA, and MBC then did the transformed counts although the difference was significant only for KPT ($P < 0.001$). The male bobwhite call count index (MBC) also correlated significantly ($P < 0.05$), but less strongly with the other indices (Table 1).

In general, the 2 harvest indices (KPT, KPA) and the untransformed BBS data revealed similar long-term trends in Illinois bobwhite abundance (Fig. 2). A minor exception was that KPT indicated a somewhat higher level of relative abundance during the 1980's and early 1990's than did the other 2 indices. One possible explanation for this is that habitat loss reduces hunting opportunity which ultimately results in fewer participants. Persisting hunters, though, may concentrate their activities in areas of remaining habitat which still support

relatively high quail densities and thus continue to do reasonably well on a per effort basis. This scenario would suggest that KPA may be a somewhat better indicator of long-term trends than KPT although the latter index would still be useful in monitoring short-term fluctuations.

The ability to predict relative hunter success prior to the season is a valuable management and administrative tool. Prior to this study, only the MBC index was used to predict subsequent fall KPT and KPA in Illinois. Based on 1975-1993 data, this variable gave R^2's of 0.67 for KPT and 0.20 for KPA statewide (Table 2). An important objective of Job 2.1 was to investigate additional variables for the purpose of improving these predictive equations. Previous studies of midwestern quail populations have demonstrated a strong link between winter weather and subsequent short-term fluctuations in abundance (Kabat and Thompson 1963, Stanford 1972, Roseberry and Klimstra 1984). In agreement with past studies, we found that days of snow cover $\geq$2.54 cm the previous winter (SNO) was the weather variable most strongly and consistently correlated with subsequent bobwhite population levels (Table 2). Roseberry and Klimstra (1984) reported cyclic trends in a long-term quail population record and noted a statistical correlation between

these oscillations and the nodal lunar cycle (Archibald 1977). We compared an annual index of this event (CYC) with regional and statewide KPT and KPA and found positive correlations in every instance although not all were statistically significant (Table 2). Roseberry and Klimstra (1984) also found a serial correlation between annual population densities; i.e., population size in any given year is a partial function of the previous year's population size. Therefore KPT the previous year (PRE) was also included as a potential predictor of current KPT. The relationship was positive and significant in all cases except the south region (Table 2). Because total harvest is strongly affected by relative hunting pressure, we included the estimated number of hunters afield (HUN) as a predictor of KPA; the relationship was positive and significant for all regions and statewide (Table 2).

Final regression equations consisted of various subsets of the above variables. Regionally, the proportion of annual KPT variance accounted for ranged from 0.46 in the south to 0.66 in the northeast; the R^2 statewide was 0.77 (Tables 3-7). For KPA, regional R^2s ranged from 0.72 in southcentral to 0.95 in the northeast and was 0.91 statewide (Tables 8-12). Observed vs

predicted levels of statewide KPT and KPA are shown in Figures 3 and 4.

Call counts from 52% of the 48 routes were moderately to strongly correlated with their respective regional means, whereas 48% were not (Table 13). The ability of individual routes to predict their regional KPT was judged good to excellent for 29% and weak to nonexistent for 71%. Using similar criteria, 40% of the routes predicted subsequent KPA in their region, whereas 60% did not. The overall performance of individual routes as predictors of subsequent fall population levels seemed highest in the westcentral region and lowest in the south region.

MANAGEMENT RECOMMENDATIONS

Burger et al. (1995:408) warned that "Bobwhite populations may not be self-sustaining under existing landscape patterns, predation regimes, and hunter harvest levels . . ." and concluded that ". . . aggressive habitat management, suppression of predation levels, and/or reductions in hunting-related mortality may be necessary." Illinois quail populations have remained relatively stable over the past 10-13 years, due in part to an unusually long series of relatively mild winters. However,

general downward population trends throughout much of the midwest and south suggest that the IDNR should continue to closely monitor the situation in Illinois. Fortunately, mechanisms are in place to accomplish this task. Post-season hunter harvest surveys should be continued and efforts directed toward gaining more timely access to the data. In addition, increased consideration should be given to using North American Breeding Bird Survey data to monitor long-term trends. Multiple regression equations developed during this study should be updated each year to improve confidence levels. In addition, there should be periodic examination of error residuals to determine if changing conditions' warrant inclusion of additional variables into the models. If access to annual BBS data could be obtained quickly enough, it might be worthwhile to investigate the possibility of using this index in place of MBC in the predictive equations, thereby eliminating the need to conduct the latter counts.

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Table 1. Correlation coefficients among various indices of bobwhite population abundance in Illinois, 1967-1993.

	KPT[a]	KPA[b]	BBS[c]	TBS[d]	MBC[e]
KPT	----	0.84**	0.90**	0.64**	0.82**
KPA		----	0.89**	0.87**	0.47*
BBS			----	0.78**	0.67**
TBS				----	0.48*
MBC					----

[a]Harvest per hunter trip.
[b]Harvest per unit area.
[c]Breeding Bird Survey data.
[d]Transformed Breeding Bird Survey data.
[e]Male bobwhite call counts (1975-93).
*$P < 0.05$.
** $P < 0.001$.

Table 2. Correlation coefficients and associated probabilities between bobwhite harvest per trip (KPT), harvest per unit area (KPA) and selected predictor variables, 1975-1993.

KPT with:	MBC[a]		SNO[b]		CYC[c]		PRE[d]	
Region	r	P	r	P	r	P	r	P
South	-0.03	0.915	-0.57	0.011	0.43	0.065	0.14	0.578
Southcentral	0.68	0.002	-0.65	0.002	0.38	0.109	0.43	0.065
Westcentral	0.63	0.004	-0.63	0.004	0.17	0.498	0.48	0.035
Northeast	0.54	0.025	-0.42	0.077	0.34	0.154	0.52	0.023
Statewide	0.82	<0.001	-0.77	<0.001	0.30	0.200	0.64	0.003

KPA with:	MBC		SNO		CYC		HUN[e]	
Region	r	P	r	P	r	P	r	P
South	0.37	0.115	-0.22	0.359	0.41	0.082	0.70	0.001
Southcentral	0.33	0.168	-0.47	0.043	0.42	0.075	0.66	0.002
Westcentral	0.56	0.012	-0.49	0.035	0.26	0.282	0.87	<0.001
Northeast	0.75	<0.001	-0.05	0.847	0.41	0.079	0.94	<0.001
Statewide	0.45	0.051	-0.40	0.080	0.50	0.024	0.78	<0.001

[a]Male bobwhite calls per stop during the previous summer.
[b]Number of days of snow cover ≥ 2.54 cm the previous winter.
[c]See text for explanation.
[d]Kill per trip the previous season.
[e]Number of quail hunters.

Table 3. Multiple linear regression analysis of bobwhite kill per unit effort, south region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per hunter trip (KPT)

N = 19
R Squared = 0.462
Adjusted R Squared = 0.395
Std. Error of Estimate = 0.279

Variable	Coefficient	Std. Error	t	P
Constant	0.832	0.648	1.285	0.217
SNO[a]	-0.011	0.004	-2.866	0.011
CYC[b]	0.019	0.009	2.020	0.060

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	1.074	2	0.537	6.872	0.007
Residual	1.250	16	0.078		
Total	2.324	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]See text for explanation.

Table 4. Multiple linear regression analysis of bobwhite kill per unit effort, southcentral region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per hunter trip (KPT)

N = 19
R Squared = 0.606
Adjusted R Squared = 0.527
Std. Error of Estimate = 0.192

Variable	Coefficient	Std. Error	t	P
Constant	0.713	0.566	1.261	0.227
SNO[a]	-0.004	0.003	-1.309	0.210
CYC[b]	0.011	0.006	1.708	0.108
MBC[c]	0.036	0.017	2.075	0.056

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	0.854	3	0.285	7.689	0.002
Residual	0.555	15	0.037		
Total	1.409	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]See text for explanation.
[c]Mean male bobwhite calls per stop the previous summer.

Table 5. Multiple linear regression analysis of bobwhite kill per unit effort, westcentral region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per hunter trip (KPT)

N = 19
R Squared = 0.582
Adjusted R Squared = 0.529
Std. Error of Estimate = 0.257

Variable	Coefficient	Std. Error	t	P
Constant	1.343	0.292	4.598	<0.001
SNO[a]	-0.008	0.003	-2.631	0.018
MBC[b]	0.047	0.018	2.650	0.018

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	1.468	2	0.734	11.120	<0.001
Residual	1.056	16	0.066		
Total	2.523	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]Mean male bobwhite calls per stop the previous summer.

Table 6. Multiple linear regression analysis of bobwhite kill per unit effort, northeast region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per hunter trip (KPT)

N = 17
R Squared = 0.662
Adjusted R Squared = 0.583
Std. Error of Estimate = 0.112

Variable	Coefficient	Std. Error	t	P
Constant	0.467	0.112	4.158	0.001
SNO[a]	-0.004	0.001	-3.266	0.006
MBC[b]	0.026	0.013	2.035	0.063
PRE[c]	0.413	0.188	2.199	0.047

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	0.320	3	0.107	8.467	0.002
Residual	0.164	13	0.013		
Total	0.484	16			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]Mean male bobwhite calls per stop the previous summer.
[c]Kill per trip the previous hunting season.

Table 7. Multiple linear regression analysis of bobwhite kill per unit effort, statewide, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per hunter trip (KPT)

N = 19
R Squared = 0.793
Adjusted R Squared = 0.767
Std. Error of Estimate = 0.116

Variable	Coefficient	Std. Error	t	P
Constant	0.973	0.216	4.500	0.001
SNO[a]	-0.006	0.002	-3.085	0.007
MBC[b]	0.051	0.014	3.721	0.002

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	0.818	2	0.409	30.606	<0.001
Residual	0.214	16	0.013		
Total	1.032	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]Mean male bobwhite calls per stop the previous summer.

Table 8. Multiple linear regression analysis of bobwhite kill per unit area, south region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per square mile (KPA)

N = 19
R Squared = 0.776
Adjusted R Squared = 0.732
Std. Error of Estimate = 3.896

Variable	Coefficient	Std. Error	t	P
Constant	-26.436	9.517	-2.778	0.014
SNO[a]	-0.139	0.056	-2.483	0.025
CYC[b]	0.443	9.132	3.345	0.004
HUN[c]	13.247	2.130	6.218	<0.001

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	790.4	3	263.5	17.356	<0.001
Residual	227.7	15	15.2		
Total	1018.1	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]See text for explanation.
[c]Estimated number of quail hunters per square mile.

Table 9. Multiple linear regression analysis of bobwhite kill per unit area, southcentral region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per square mile (KPA)

N = 19
R Squared = 0.724
Adjusted R Squared = 0.669
Std. Error of Estimate = 4.687

Variable	Coefficient	Std. Error	t	P
Constant	-48.725	13.913	-3.502	0.003
MBC[a]	0.798	0.313	2.550	0.022
CYC[b]	0.450	0.159	2.833	0.013
HUN[c]	16.368	3.266	5.011	<0.001

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	864.5	3	288.2	13.116	<0.001
Residual	329.6	15	22.0		
Total	1194.0	18			

[a]Number bobwhite calls per stop the previous summer.
[b]See text for explanation.
[c]Estimated number of quail hunters per square mile.

Table 10. Multiple linear regression analysis of bobwhite kill per unit area, westcentral region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per square mile (KPA)

N = 19
R Squared = 0.848
Adjusted R Squared = 0.829
Std. Error of Estimate = 3.519

Variable	Coefficient	Std. Error	t	P
Constant	-19.699	4.553	-4.327	0.001
MBC[a]	0.732	0.236	3.104	0.007
HUN[b]	14.333	1.918	7.471	<0.001

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	1107.2	2	553.6	44.709	<0.001
Residual	198.1	16	12.4		
Total	1305.4	18			

[a]Number bobwhite calls per stop the previous summer.
[b]Estimated number of quail hunters.

Table 11. Multiple linear regression analysis of bobwhite kill per unit area, northeast region, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per square mile (KPA)

N = 19
R Squared = 0.949
Adjusted R Squared = 0.942
Std. Error of Estimate = 0.746

Variable	Coefficient	Std. Error	t	P
Constant	0.285	0.490	0.582	0.569
SNO[a]	-0.036	0.008	-4.443	0.001
HUN[b]	4.814	0.280	17.175	<0.001

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	164.6	2	82.30	147.8	<0.001
Residual	8.9	16	0.56		
Total	173.5	18			

[a]Number of days of snow cover ≥ 2.54 cm the previous winter.
[b]Estimated number of quail hunters per square mile.

Table 12. Multiple linear regression analysis of bobwhite kill per unit area, statewide, Illinois, 1975-1993.

Dependent Variable: Annual bobwhite kill per square mile (KPA)

N = 19
R Squared = 0.913
Adjusted R Squared = 0.888
Std. Error of Estimate = 1.549

Variable	Coefficient	Std. Error	t	P
Constant	-10.210	4.445	-2.297	0.038
MBC[a]	0.480	0.186	2.579	0.022
SNO[b]	-0.072	0.025	-2.866	0.012
HUN[c]	8.216	0.890	9.229	<0.001
CYC[d]	0.118	0.057	2.082	0.056

Analysis of Variance

Source	Sums-of-Squares	DF	Mean Square	F	P
Regression	352.9	4	88.23	36.768	<0.001
Residual	33.6	14	2.40		
Total	386.5	18			

[a]Number of male calls per stop during previous summer.
[b]Number of days of snow cover ≥ 2.54 cm the previous winter.
[c]Estimated number of quail hunters per square mile.
[d]See text for explanation.

Table 13. Correlation[a] of annual call counts from individual routes with their respective regional mean call counts, kill per trip, and kill per area, 1984-1993.

Route	Call Counts[b]	Kill/Trip	Kill/Area
South Region			
Gallatin-Hardin	***	-	*
Jackson	-	-	**
Massac	***	-	**
Pope-Johnson	**	-	-
Pulaski	*	-	*
Saline	***	-	**
Union	**	-	*
Williamson	*	-	*
Southcentral Region			
Clark	-	*	-
Clay	*	***	-
Clinton	**	-	-
Crawford	*	-	**
Cumberland	*	**	*
Edwards	***	-	**
Effingham	-	***	**
Fayette W	***	*	*
Fayette E	-	**	-
Franklin	**	-	**
Hamilton	**	-	***
Jefferson	***	*	***
Lawrence	**	-	***
Madison	**	-	*
Marion	*	*	-
Monroe	***	**	-
Perry	*	-	-

Table 13. Continued.

Route	Call Counts[b]	Kill/Trip	Kill/Area
Randolph	*	–	*
Richland	***	–	*
St. Clair	–	*	–
Shelby	–	*	–
Wabash	**	–	–
Washington	**	–	*
Wayne	*	*	**
White	***	*	–
Westcentral Region			
Adams	***	***	***
Brown	–	–	*
Cass[c]	***	***	***
Fulton	***	***	***
Hancock	***	**	**
Henderson	*	**	*
Jersey	*	*	**
Macoupin	–	*	*
Montgomery	–	*	–
Morgan	***	–	–
Peoria	*	***	*
Pike	**	**	**
Schuyler	***	***	***
Scott	–	*	–
Warren	*	**	*

[a] *** r = +0.70-1.00
** r = +0.50-0.69

* $\underline{r}$ = +0.30-0.49

\- $\underline{r}$ < +0.30

[b]Regional mean does not include route being tested.

[c]1989-1991.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Job 2.2: **Monitor upland wildlife habitat conditions**

Objective: To recommend efficient, cost-effective methods of periodically monitoring land use/habitat conditions in Illinois as they affect upland wildlife.

INTRODUCTION

The distribution and abundance of upland wildlife in Illinois are determined primarily by prevailing land use/cover patterns at both local and landscape scales. Virtually all upland wildlife habitat in Illinois is created or maintained incidentally to other forms of land use, mainly agricultural. The quantity and quality of this habitat is a function not only of landscape composition, but spatial patterns as well. To effectively manage upland wildlife resources, it is essential that managers have access to reasonably current information regarding land use/cover conditions on a regional and statewide basis.

METHODS

In conjunction with Phase I of W-106-R, 16 categories of land cover types within a 0.8-km-wide corridor along 49 bobwhite

call count routes were identified and mapped by IDNR biologists during field inspections in early summer 1991. To facilitate current and future analysis, these data were digitized and entered into a GIS using the following protocol:

1. Land cover within a 0.8-km corridor along call count routes was delineated by field inspection and recorded on 30 x 30" (1:12,600 scale) black and white aerial photographs.
2. Small format (9 x 9") black and white aerial photographs of each route were digitized by electronically scanning at 200 dpi.
3. Individually scanned photos were merged into one image for each route that was then georeferenced.
4. Land cover types marked on the large format aerial photos were transferred to the scanned image using INTERPRET RASTER features of the Map and Image Processing System (MIPS) software.
5. Separate vectors representing the call count route and individual stops were created and overlaid on the scanned image.

6. Vectors representing 0.4-km buffers along each route were created and converted into binary rasters for use as processing masks.
7. Cover types within the processing mask were identified and marked.
8. Land cover summary statistics were generated and downloaded to dbase III+ files.

Land cover along each of the 49 male bobwhite call routes was then compared to county-wide conditions in their respective counties based on the classified satellite imagery (Job 1.1). For this comparison, the 16 categories recorded along call routes were aggregated into 5 classes coinciding with the Landsat TM classification. Call routes that extended into 2 counties were compared to the mean composition of those counties weighted according to how much of the route was in each. To obtain a comparative index of agreement, the absolute difference in percent composition of each individual route and its respective county were determined for cropland, grassland, and woods and all other categories and a mean taken of these absolute differences. Call routes were then placed into classes representing mean differences of <5, 5-10, 11-15, and 16-20%.

RESULTS AND DISCUSSION

Land use/cover along the 49 bobwhite call count routes in westcentral, southcentral, and southern Illinois was recorded in June 1991 (Table 1). Cover conditions along most routes were reasonably representative of their respective counties as determined from classified Landsat 5 TM satellite imagery. The average deviation in percent composition for the broad categories of cropland, grassland, woods, and all other types ranged from a low of 1% for the Christian County call route to highs of 16-18% for the St. Clair and Madison county routes. Overall, 42 routes varied less than 10% from their respective counties whereas 7 routes differed by more than 10% (Fig. 1). The area surveyed along each route was 10 square miles (20 x 0.5 m) and averaged 2% of the total county area. Notwithstanding that transects were established for purposes other than recording land cover and did not represent random samples, land use/cover along most routes as of 1991 appeared to be reasonably representative of the counties in which they were located. The question of whether changes over time would be equally representative was not addressed by this study.

MANAGEMENT RECOMMENDATIONS

The 2 methods of obtaining land use/cover information used in this study represent extremes in spatial scale (extent of coverage and ground resolution) and informational content. Field inspections along bobwhite call count routes provided accurate, detailed information from relatively small areas whereas classification of satellite imagery provided less accurate, less detailed information over very large areas. We believe the 2 approaches should be viewed as complimentary rather than alternative methods. Regular, standardized field inspections along call routes could provide valuable information regarding specific land use/cover conditions and farming practices that would not be discernable from satellite coverage. Conversely, classified satellite imagery provides information about regional conditions and spatial landscape patterns not available from on-site field inspections. Unless management objectives warrant otherwise, we recommend that land use/cover conditions should be monitored at a minimum of 5 and a maximum of 10-year intervals. In addition, we believe that the complimentary nature of the 2 data sources would be maximized if they were obtained during the same growing season.

Table 1. Land use (%) within 0.8-km corridor along bobwhite call count routes, June 1991.

County	Corn	Beans	Milo	Wheat	Hay	Past	CRP	ACR	Grass	Eidl[a]	Midl[b]	Lidl[c]	Dec[d]	Pine	Ornu[e]	Water	Nonh[f]	Misc
Adams	27.1	26.8	0.2	7.1	4.2	14.9	3.2	0.0	0.4	0.3	0.1	0.3	10.6	0.0	0.0	0.6	2.5	1.7
Brown	24.5	19.1	0.0	2.8	0.4	15.4	3.4	0.0	0.0	1.2	0.6	0.2	28.5	0.0	0.0	0.8	1.7	1.4
Cass	45.3	33.8	0.0	2.1	2.0	5.5	1.1	0.0	0.0	0.7	0.0	1.6	3.5	0.0	0.0	0.2	2.3	2.0
Christian	35.1	26.7	0.0	11.7	3.1	7.9	0.1	0.6	3.4	1.3	0.7	0.3	4.5	0.0	0.0	0.5	2.5	2.1
Clark	34.9	24.1	0.0	7.8	1.9	5.7	0.9	0.0	0.8	0.7	0.0	3.9	13.5	0.0	0.0	0.9	2.6	2.5
Clay	41.6	22.5	0.0	11.3	2.7	3.9	0.9	0.0	1.0	0.0	0.2	0.1	10.1	0.0	0.0	0.2	3.8	1.7
Clinton	25.7	31.0	1.1	18.3	6.4	3.2	0.1	0.0	0.0	1.6	0.3	1.1	5.2	0.0	0.0	0.7	3.3	1.9
Crawford	34.2	29.1	0.0	9.3	0.9	0.3	0.7	0.0	0.3	2.5	0.4	0.5	16.9	0.0	0.0	0.4	2.4	2.1
Cumberland	35.8	33.2	0.0	7.3	0.7	1.4	0.8	0.0	1.0	1.2	1.0	1.3	11.4	0.0	0.0	0.9	2.2	1.9
Edwards	25.7	18.8	0.0	16.9	3.1	11.0	3.7	0.3	0.8	0.8	2.4	1.1	11.2	0.0	0.0	0.6	2.2	1.5
Effingham	26.7	24.2	0.3	9.5	4.5	6.2	2.8	0.0	0.9	0.7	0.7	0.7	19.0	0.1	0.0	0.6	3.2	0.0
Fayette E	26.8	27.7	0.4	8.9	4.4	4.0	5.1	0.3	0.1	0.3	0.1	1.5	5.3	0.0	0.0	1.1	7.7	6.3
Fayette W	32.6	29.1	0.1	11.7	2.2	2.9	4.9	0.0	1.0	1.2	1.0	0.0	9.1	0.0	0.0	0.3	1.4	1.9
Franklin	22.7	32.7	3.0	2.8	0.2	8.7	6.2	0.0	2.1	1.4	0.4	0.0	15.0	0.3	0.0	0.9	2.2	1.5
Gallatin	6.0	8.0	0.0	0.0	3.7	22.0	2.9	0.0	0.5	0.0	0.4	5.0	38.6	7.1	0.2	0.3	3.3	2.2
Hamilton	18.3	21.8	2.7	3.8	1.7	6.4	18.1	0.0	1.8	0.7	0.6	0.2	18.7	0.0	0.0	0.4	2.5	2.4
Hancock	32.2	31.0	0.0	5.8	4.4	13.8	4.9	0.0	0.0	0.0	0.1	0.0	3.5	0.0	0.0	0.1	4.2	0.0
Henderson	37.1	17.0	1.0	2.7	5.9	4.4	0.0	0.0	2.3	0.0	0.1	0.9	13.9	11.2	0.0	0.6	3.1	0.0
Jackson	4.3	1.7	0.4	0.6	14.8	12.7	2.0	0.0	0.2	1.0	2.0	2.0	44.5	0.6	6.8	0.6	3.4	2.5
Jefferson	23.7	19.8	1.9	9.0	0.0	7.0	13.5	0.0	1.8	0.7	0.0	0.0	16.5	0.3	0.0	0.5	3.2	2.0
Jersey	25.2	16.7	0.0	7.9	7.6	7.0	2.3	0.0	0.0	0.6	0.5	0.1	26.4	0.0	1.9	0.7	1.7	1.7
Lawrence	39.2	21.3	0.0	6.0	1.4	1.7	1.8	0.0	0.5	6.6	0.3	1.4	14.8	1.4	0.0	0.3	2.0	1.8
Macoupin	29.2	27.2	0.0	6.4	5.1	9.1	1.8	0.8	1.3	0.1	0.2	0.4	12.5	0.0	1.0	1.1	2.6	1.4
Madison	31.0	28.4	0.0	19.7	4.9	3.1	0.0	0.0	2.5	0.0	0.0	0.0	4.5	0.0	0.1	1.0	3.2	1.7
Marion	19.2	21.6	0.0	11.1	1.6	11.2	2.1	0.0	1.3	0.1	0.0	0.2	26.8	0.0	0.0	0.7	2.2	1.9
Massac	17.1	13.2	4.0	1.9	12.4	13.0	4.6	0.0	0.9	0.9	0.1	0.3	21.8	0.0	1.2	0.8	5.0	2.8
McDonough	27.8	12.8	0.0	7.8	3.4	22.7	0.0	0.0	1.4	0.0	0.0	2.1	14.7	0.0	0.0	1.5	3.5	2.4
Monroe	18.0	24.0	0.0	17.0	6.2	3.4	2.6	0.0	0.5	1.5	0.2	0.5	18.3	0.0	0.0	1.3	4.2	2.4
Montgomery	20.4	27.5	0.8	14.2	3.8	6.7	3.5	0.0	0.0	0.6	0.6	1.2	13.8	0.0	0.0	2.7	2.6	1.7
Morgan	34.8	27.5	0.0	5.1	2.3	10.7	0.1	0.9	1.4	0.3	0.8	0.2	10.1	0.0	0.0	0.6	2.5	2.9
Peoria	32.0	25.9	0.0	9.7	2.6	9.5	0.3	0.0	2.6	0.0	0.1	0.3	10.8	0.0	0.2	0.9	5.1	0.0
Perry	20.0	25.2	0.0	15.5	6.9	5.7	3.3	1.9	1.8	0.4	0.4	0.0	14.6	0.0	0.0	0.9	3.4	0.0
Pike	26.4	12.1	0.0	10.3	1.7	10.6	5.7	0.0	2.0	5.8	0.4	0.2	18.5	0.0	0.0	0.5	3.3	2.7
Pope	0.6	0.1	0.0	0.0	3.9	11.5	3.6	0.0	0.1	0.4	1.1	5.3	47.2	22.3	0.0	0.3	2.0	1.6
Pulaski	12.9	20.8	1.0	6.5	3.0	15.4	8.3	0.0	0.9	2.7	2.2	2.1	18.8	0.0	0.0	0.9	2.4	2.2

Table 1. Continued.

County	Corn	Beans	Milo	Wheat	Hay	Past	CRP	ACR	Grass	Eidl[a]	Midl[b]	Lidl[c]	Dec[d]	Pine	Ornu[e]	Water	Nonh[f]	Misc
Randolph	16.0	21.0	0.0	13.0	9.6	7.0	4.9	0.0	0.5	2.3	0.1	1.1	18.7	0.0	0.3	0.9	2.7	1.9
Richland	30.6	28.4	0.0	9.6	2.5	1.9	0.2	0.0	0.2	4.2	0.0	0.5	16.8	0.0	0.0	0.4	3.0	1.7
St. Clair	32.9	29.2	0.2	21.2	2.6	1.3	1.7	0.7	0.7	0.1	0.0	0.2	3.2	0.0	0.0	0.3	3.5	2.3
Saline	32.2	26.9	0.0	5.1	2.8	4.4	0.7	0.0	1.1	3.7	2.3	1.7	12.2	0.0	0.0	1.1	3.5	2.3
Schuyler	26.4	20.6	0.0	5.9	4.6	6.6	1.5	0.0	0.1	2.1	0.9	2.6	21.6	0.0	0.0	2.0	3.3	1.9
Scott	30.6	27.0	0.0	5.4	4.6	9.4	1.7	0.3	2.7	0.6	0.8	0.5	12.5	0.0	0.0	0.6	1.5	1.9
Shelby	20.8	27.9	0.0	10.2	0.7	3.7	2.4	0.0	1.2	2.1	0.0	0.0	15.4	0.0	0.6	0.2	2.0	2.6
Union	12.4	16.0	0.0	1.9	2.5	12.7	5.3	0.0	0.9	1.3	0.6	0.4	40.5	0.0	0.0	1.7	1.6	2.2
Wabash	35.3	28.2	0.0	6.3	0.5	3.4	1.7	1.6	1.8	0.4	1.2	0.2	13.8	0.0	0.0	1.5	2.0	2.0
Warren	41.5	29.7	0.0	0.8	2.2	11.8	0.4	0.2	1.9	0.1	0.0	0.4	6.7	0.0	0.0	0.6	3.8	0.0
Washington	19.4	21.7	1.1	17.0	6.2	4.3	1.0	0.0	0.8	3.8	0.3	0.9	17.5	0.0	0.2	1.0	2.9	1.9
Wayne	22.2	23.0	0.2	10.3	14.0	10.3	4.6	0.0	1.4	0.3	0.0	0.1	9.7	0.0	0.2	0.3	1.9	1.7
White	26.9	17.7	0.0	15.6	1.9	7.3	0.0	1.3	1.3	1.8	0.7	0.5	19.7	0.0	0.4	0.9	2.2	2.0
Williamson	5.9	4.1	0.0	1.2	2.5	21.7	3.6	0.0	1.2	2.1	0.3	1.4	42.6	0.0	0.0	3.5	7.4	2.6

[a]Early oldfield
[b]Mid oldfield
[c]Late oldfield
[d]Deciduous forest
[e]Orchard/Nursery
[f]Nonhabitat

Figure