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ERTS-1 DATA APPLICATIONS TO
MINNESOTA FOREST LAND USE CLASSIFICATION

by

Ralph G. Eller
Merle P. Meyer
Joseph J. Ulliman

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by the
Institute of Agriculture
Remote Sensing Laboratory
College of Forestry
University of Minnesota
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Ralph G. Eller[2]
Merle P. Meyer
Joseph J. Ulliman

Institute of Agriculture Remote Sensing Laboratory
College of Forestry
University of Minnesota

ABSTRACT

Color-combined ERTS MSS spectral slices were analyzed to determine the maximum (repeatable) level of meaningful forest resource classification data visually attainable by skilled forest photo interpreters for the following purposes: (1) periodic updating of the Minnesota Land Management Information System (MLMIS) statewide computerized land use databank, and (2) to provide first-stage (extensive) forest resources survey data for large-area forest land management planning. Controlled tests were made of two forest classification schemes by experienced professional foresters with special photo interpretation training and experience. The test results indicate it is possible to discriminate the MLMIS "forest" class from the MLMIS "nonforest" classes - but that it is not possible, under average circumstances, to further stratify the "forest" classification into species components with any degree of reliability with ERTS imagery.

An ongoing test of the resulting classification scheme involves the interpretation, and mapping, of the south half of Itasca County, Minnesota, with ERTS imagery. This map is now undergoing field checking by on-the-ground field cooperators, whose evaluations will be completed in the fall of 1973.

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INTRODUCTION

This constitutes a report on a study by the Institute of Agriculture Remote Sensing Laboratory (IARSL) to determine the practical applicability of ERTS-1 data to the classification of Minnesota's forest resources (Figure 1) into meaningful management categories. The ability to discriminate forest lands from non-forest, the attainable levels of forest cover type categorization, and the minimum discernable ground unit area identifiable with ERTS-1 data, were all investigated. The ultimate compatibility of these ERTS-derived forest resource land use data with the Minnesota Land Management Information System's (MLMIS) statewide computerized databank of land use information is now being explored on a preliminary basis.

Thirty-seven percent of Minnesota's total land area of over 50,000,000 acres is forest land. Commercial forest land occupies 1/3 of the state's land area - a total of some 16,875,000 acres and the major vegetation cover types on this land include the following:

Conifers
> Pine (jack, red, white)
>
> Spruce-fir and tamarack

Hardwoods
> Oak
>
> Lowland hardwoods (elm, ash, cottonwood)
>
> Northern hardwoods (maple, birch, basswood)
>
> Aspen-birch

Other
> Shrublands (upland and lowland)
>
> Marsh and bog
>
> Grassland
>
> Other open (cultivated, cleared)

Over 8,000,000 acres of Minnesota's commercial forest land is in relatively large units managed by public agencies such as the U. S. Forest Service (2 national forests totalling 2,127,000 acres), the state (55 state forests totalling 3,304,000 acres) and the counties (over 3,000,000 acres). With a few exceptions, private ownerships (totalling 7,490,000 acres) are rather small and scattered.(1)
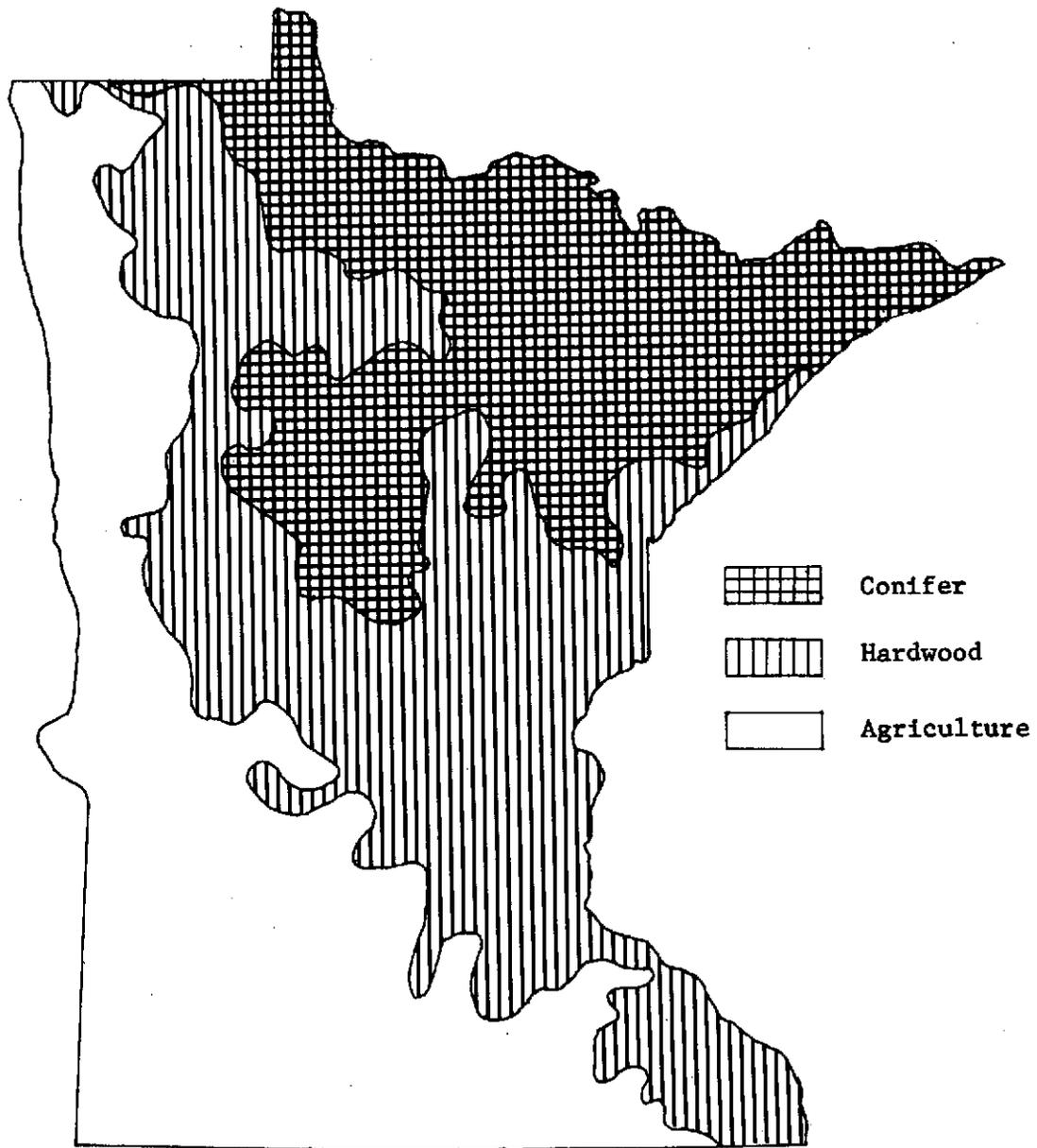
Figure 1. Generalized extent of Minnesota forest land.

Legend:
- Conifer
- Hardwood
- Agriculture

Minnesota's forests play an important role in the work life and leisure time pursuits of people both in Minnesota and from surrounding states. For example, some 44,000 persons are involved in some phase of timber harvest, processing, distribution and other allied industries. After initial processing, the wood raw materials are valued at $369,000,000, and when processed into completed products, a further value is added for a total of approximately 500 million dollars. This level of activity places the forest products industry third in importance in the state behind agriculture (first) and mining (second) (2).

Minnesota's forest lands are both intensively and extensively used for various recreational activities. Big and small game hunting, camping, canoeing, snowmobiling and hiking are major recreational pursuits. The Boundary Waters Canoe Area (BWCA) and the newly-established Voyageurs National Park are two large areas of Minnesota set aside for purely recreational activities. On Minnesota's State Forests alone, some 222,830 camper-days were reported for the 1972 fiscal year, and a total of 566,181 resident big and small game licenses were sold in 1972.

Minnesota land use planners or resource managers in any particular natural resource discipline, are presented with complex questions in their work. These questions are increasingly complicated by population trends, with resulting development of all types, and more and more demanding restrictions concerning alteration of the landscape or the resource that is on (or in) it. Timber harvest and mineral prospecting on Superior National Forest lands are, for example, under court challenge, and the Voyageur's National Park was established only after considerable controversy.

This investigation was initiated to test ERTS data applicability to the continuing monitoring process necessary at all levels of forest resource planning and management. If an ERTS-based resource monitoring system could be employed in practical land management work, the information requirements of such activities could be met with less than one-year-old photographic or digital data in significantly shorter time than with conventional survey methods.

It was hypothesized that ERTS forest scenes could be interpreted and mapped in detail much as conventional aerial photos are used in forest land management planning. ERTS data involved in this study consisted of bulk

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70mm B&W MSS multispectral scenes which were combined and color-enhanced with the IARSL color-additive viewing system. Color density level-slicing techniques were also employed, but only on a very limited, preliminary, basis.

STUDY AREA LOCATIONS, CHARACTERISTICS

The investigation study units are located in northeast, north-central, and southeast portions of Minnesota's forested region in conjunction with 1972 RB57F overflight coverage (Figure 2).

The Cook County Study Area includes the Superior National Forest, as well as other public and private lands. This part of Minnesota is only sparsely settled, and any one locality is only periodically occupied by U. S. Forest Service personnel or recreationists. The large land surface including this study area has considerable exposed rock and extensive shallow surface soils with underlying rock. The topography has mainly been molded by glaciation, which is especially evident in the lake patterns seen in broad areas when viewing ERTS images. Stereoscopic viewing of conventional aerial photos reveals sectors exhibiting sharp relief (i.e., hills as opposed to mountainous terrain). Forest cover types present include large areas of aspen along with jack pine, spruce-fir, black spruce and some red (Norway) pine and northern hardwoods. In general, the forest here is an important source of wood fiber and, as a consequence, timber harvest patterns are evident in some localities. The study area is also extremely important in terms of recreation uses.

The Chippewa National Forest Study Area is located in west-central Itasca County, in close proximity to the western portion of Minnesota's Iron Range, and is characterized by flat to gently rolling terrain with numerous wet lowlands. Most of it is wooded, with only occasional cultivated lands, pasture, or extractive operations. A variety of forest cover types are present: aspen, northern hardwoods, jack pine, spruce-fir, and extensive areas of black spruce-tamarack bog. Aspen and northern hardwoods dominate the woodland types, and substantial portions of the wet lowlands are occupied by lowland shrubs, immature black spruce or stagnant black spruce. Much of the land in this study area produces significant amounts of timber for area paper mills, sawmills and board plants.

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Interpretation
Test Unit

Chippewa
National Forest
Study Area

Interpretation
Test Unit

Cook
County
Study
Area

Interpretation
Test Unit

Southeast
Minnesota
Study Area

25   0   50   100   150   200

Miles
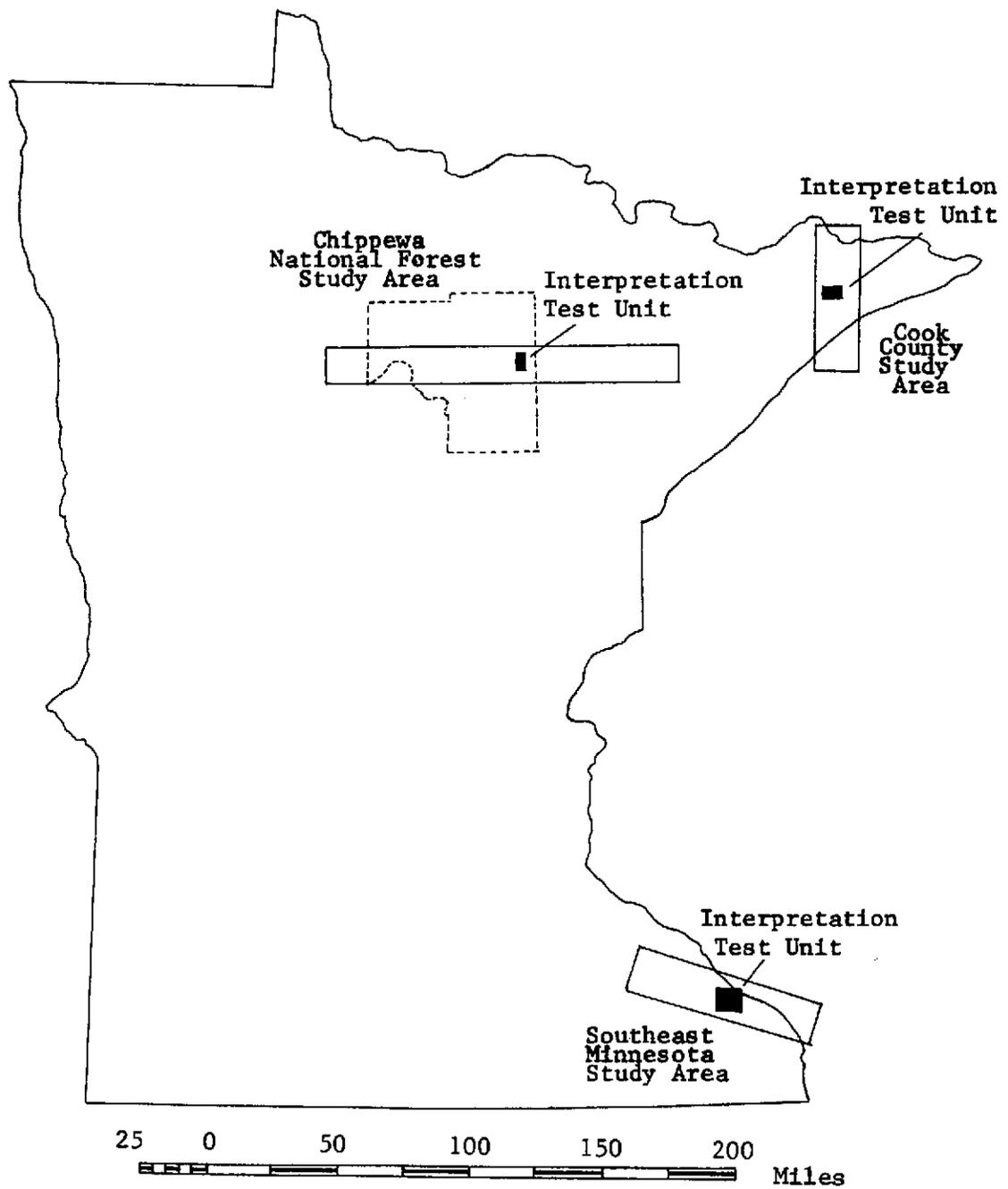
Figure 2. Study areas, interpretation test units, RB57F June 6, 1972 underflight coverage, and outline of Itasca County (broken line).

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The Southeast Minnesota Study Area is a uniquely interesting part of the state located in southeast Minnesota along the Mississippi River (Minnesota-Wisconsin border). It is characterized by steep, loess bluffs, part of a deeply entrenched dendritic drainage system. The study area is in proximity to Winona, Minnesota, and includes lowland areas of shrubs and bottomland hardwoods adjacent to the Mississippi River, and upland areas on the bluffs and in the valleys of the drainage system. Cultivated lands, pasture, and other open areas occupy the tablelands on top of the bluffs, as well as the areas of flat or rolling topography in the valleys between the bluffs. Oaks and northern hardwoods occupy the steep grades on the bluff sides, with oak types dominant. These hardwood stands and other vegetation play a critical role in holding the unstable soil in place on the hillsides. Parts of the Winona urban area do extend into the study area, and almost all of the study area, except for the steep hillsides, is cultured in one way or another.

OBJECTIVES

This study has two major objectives: (a) determine the practical applicability of ERTS data to the classification of forest resources into meaningful management categories, and (b) ascertain the compatibility of these ERTS-derived forest resource data with the Minnesota Land Management Information System (MLMIS) statewide computerized land use databank.

Since the possible degree of classification of forest resources attainable with ERTS data is basic, the work of the past year has concentrated on this aspect of the overall study. Not only must the attainable, practical classification levels be ascertained, but also the techniques whereby they may be achieved and the relative degree of repeatability of the detection techniques under different seasonal and image quality conditions. More specifically, some of the questions under study which relate to the interpretation process of interpretation of the ERTS imagery are the following:

1. What are the combinations of ERTS spectral slices and associated filter combinations which, when used in the color additive viewer, best portray natural/cultural feature differences?

2. What approximate number of scene color contrasts are readily discernable and to what degree are they repeatable?

3. What is the minimum ground area readily interpretable on projected (enlarged) false-color ERTS scenes?

4. To what level of classification can Minnesota forest lands be delineated or recognized on (enlarged) false-color ERTS scenes?

5. How well can forest vegetation classes be distinguished from other (natural and/or cultural) features?

STUDY DESIGN, DATA COLLECTION

Introduction

The first requirement of this ERTS data applicability test was development of adequate test areas for which valid ground truth was (or would be) available. Initially, the statewide 40-by-40 classification accomplished for the first Minnesota Land Management Information System (MLMIS) databank (3, 4) was considered as a possible source of ground truth. These data had been derived from the interpretation of 1968 1:90,000 scale leafoff panchromatic aerial photography into the following dominant land use classes:

1. Forested.
2. Cultivated.
3. Water.
4. Marsh.
5. Urban residential.
6. Extractive.
7. Pasture and open.
8. Urban non-residential or mixed residential development.
9. Transportation.

Hopefully, ERTS data would be capable of providing a further breakdown of the MLMIS "forested" class into various species components. But as a logical prelude, tests had to be made to insure that ERTS could, at the least, identify forest land per se no less accurately than the MLMIS small scale aerial photo interpretation method. Accomplishment of a test of this

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nature required the availability of adequate, highly reliable, ground truth in the test areas. Initial plans called for the use of the MLMIS ground data; however, after a thorough review of the 1968 photographs and the associated interpretation results, the use of existing MLMIS 40-by-40 land use information in the ERTS tests was abandoned for the following reasons:

1. Because of the difficulty of locating individual forty-acre tracts in forested areas, it was not possible in some cases to know whether the same forty could be identified on a repeat basis.

2. Due to the absence of a statistically-controlled system of ground checking on the original small scale aerial photo interpretation, there was no valid method of ascribing a viable standard of accuracy to the interpretation and thus no safe basis for comparison with the ERTS interpretation data.

Ultimately, in actual management situations, these problems will not necessarily eliminate the possibility of using the MLMIS system as originally developed. It is questionable whether such a 40-by-40 system could be developed for forested areas where individual forty data could repeatedly be retrieved with acceptable reliability at a reasonable cost; however, in typical large-area forest management, aggregations of forties are usually the basis for management and absolute boundary definitions of individual forties at this management information stage are not a necessity. But for a valid test of ERTS data applications, ground truth was required which was more precisely located and specifically classified than the initial MLMIS data base.

Because of lack of any prior experience, possible success in the use of ERTS image analysis for forest identification and classification purposes was difficult to predict. However, on the basis of findings in a recent study by Douglass and Meyer (5) in the Chippewa National Forest Study Area, involving a carefully-controlled test of the utility of NASA RB57F small and very small scale color and color infrared photography to discriminate forest cover types, there appeared reason to suspect the ability of ERTS to discriminate forest species groups. In this preliminary study, 5 of the Forest's professional management personnel, all with considerable aerial photo interpretation experience, were given specialized training in the use of small and very small scale aerial photography. Their average absolute

scores on the determination of the four basic cover types (aspen, spruce-fir, pine and northern hardwoods) are indicated in Table 1.

In summary, Douglass and Meyer suggest that reduction in aerial photo image scales to 1:400,000 and smaller, materially reduces the capability of even very skilled professional interpreters to stratify Minnesota forest cover into individual species or even species groups. It also suggests that, except for special circumstances, ERTS imagery perhaps cannot be expected, on the average, to provide forest cover type discrimination capabilities much beyond the existing MLMIS classifications of "forest" and "nonforest."

ERTS Display and Analysis System

Unenhanced Individual B&W ERTS Spectral Bands. A number of these were initially analyzed by projecting the ERTS scenes mounted in 3 1/4x4-inch glass slides to a scale of 1:120,000 for matchup with annotated test area 1:120,000 scale NASA RB57F color 9x9-inch transparencies. The objective was to determine the number of meaningful B&W contrast levels visible on bulk ERTS scenes of training areas in southeast and north central Minnesota.

A gray tone contrast study of ERTS Band 5 (12 August 1972) and Band 6 (7 October 1972) indicated a number of distinguishable gray tone contrast levels which, when compared to field-checked aerial photography, related to a number of vegetative and cultural features. But the problem was to establish any degree of repeatability in view of the high degree of (visual) crossover of the same image gray level between different features on the ground.

Color-Combined ERTS Spectral Bands. Color-combined scenes were found to be superior to the individual unenhanced B&W spectral bands (Figures 3, 4, 5 and 6). Repeated combining and color enhancement of ERTS scenes revealed that MSS Band 5, in registration with one of the infrared bands (6 or 7), produced the best composites. The color filters resulting in the best false color composite were green with Band 5 and red with Band 6 or 7.

Density Level-Slicing Enhancement of Individual Bands or Composites. These were considered in only a preliminary fashion. Since the color-combined scenes, in themselves, appeared to afford the greatest promise for an economical classification tool, in-depth exploration of level-slicing technique applications was postponed. Examples of some initial results obtained with density level-slicing are shown in Figures 5 and 6.

Table 1. Degree of success achieved in discrimination of 4 basic forest cover types by 5 trained Chippewa National Forest photo interpreters using NASA RB57F color infrared photography. Note that the detectability of northern hardwoods increased from 50% for the 1:120,000 scale 8/6/71 photography to 80% for the 1:460,000 scale 9/29/71 photography (*). This was due to the more highly visible fall coloration of the northern hardwoods in September, as compared to the photography flown in August prior to fall coloration.

Cover type	Color infrared photo scale		
	1:60,000[1]	1:120,000[1]	1:460,000[2]
	-percent interpretation success achieved-		
Aspen	100%	100%	80%
No. hardwoods	90%	50%*	80%*
Spruce-fir	90%	80%	60%
Pine	100%	90%	50%
All hardwoods	100%	100%	95%
All conifers	100%	100%	80%

[1] Flown August 6

[2] Flown September 29

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Figure 3. Location of Chippewa National Forest study area on an ERTS scene. Itasca County and interpretation test unit are outlined.
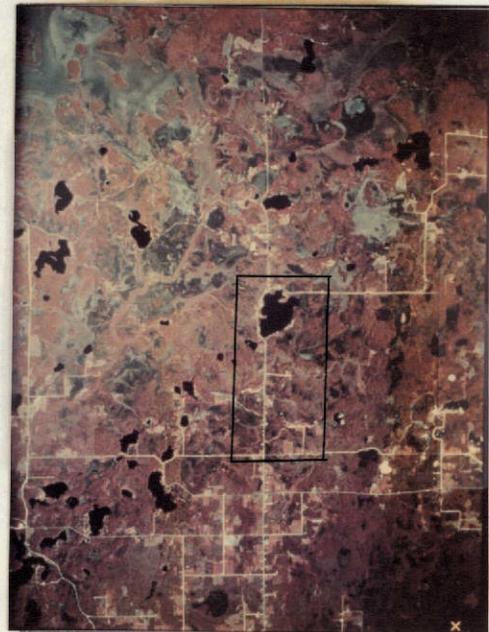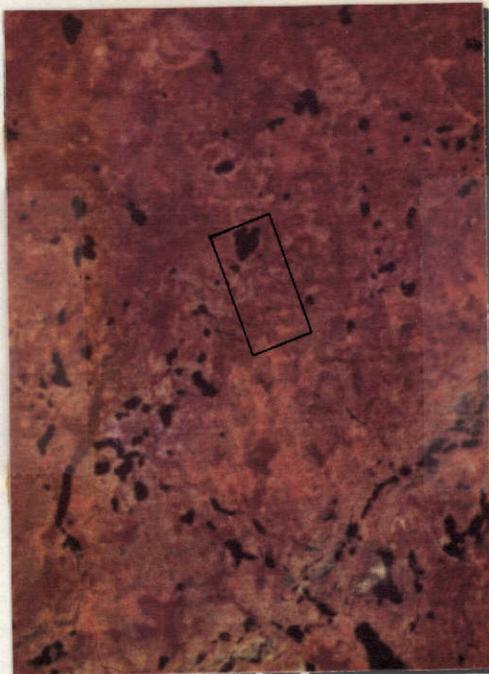
Figure 4. Close-up of the Chippewa National Forest test interpretation unit, as seen on an ERTS color-combined October 7, 1972 scene (left), and on an RB57F June 6, 1972, color infrared photograph (right).
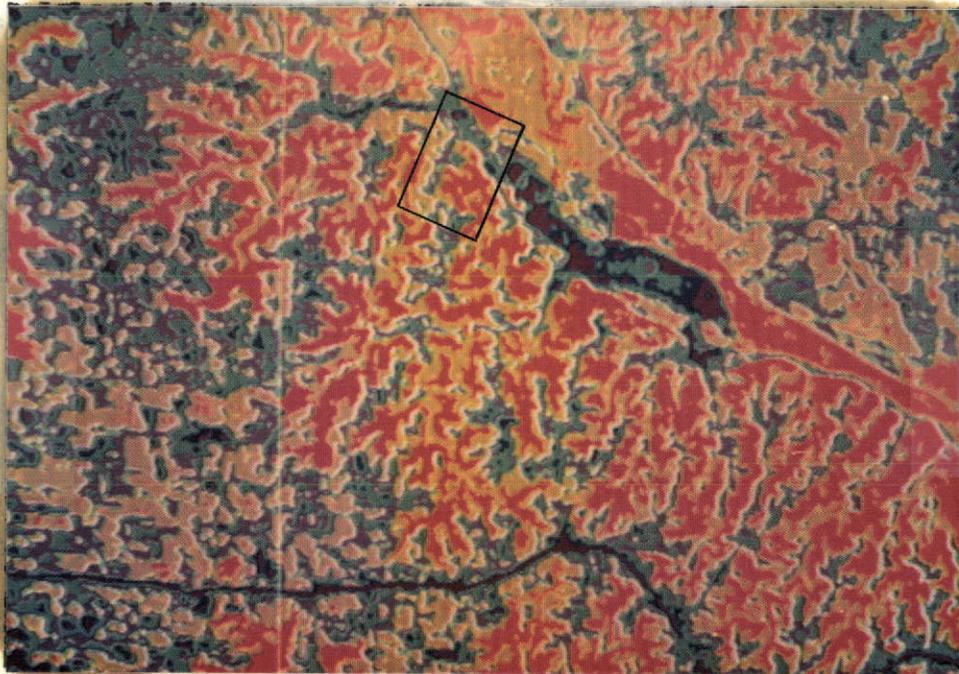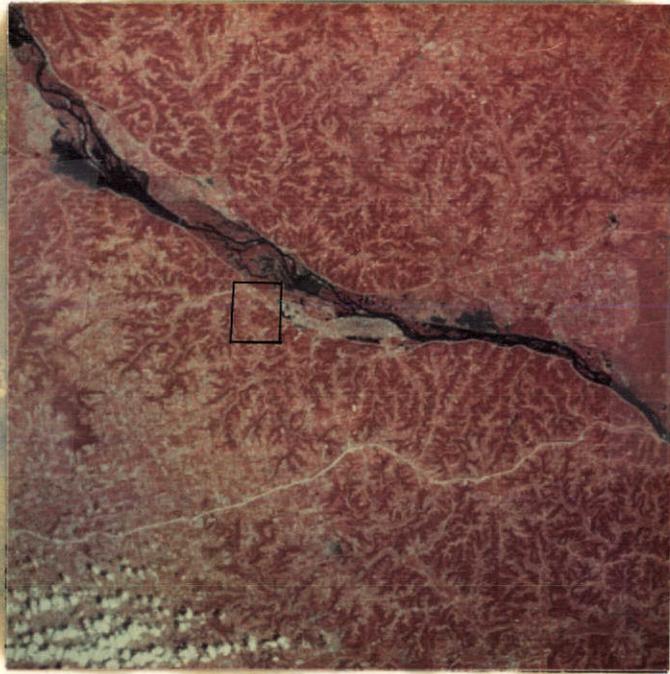
Figure 5. Southeast Minnesota study area and interpretation test unit as seen on color-combined (above) and density level-slice (below) renditions of an ERTS August 12, 1972, scene.

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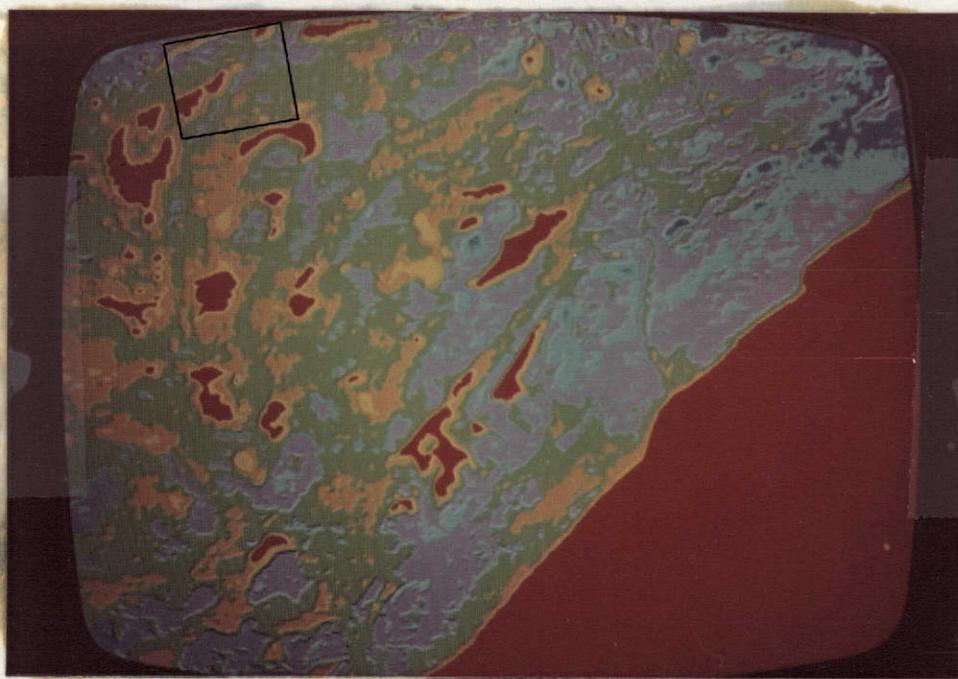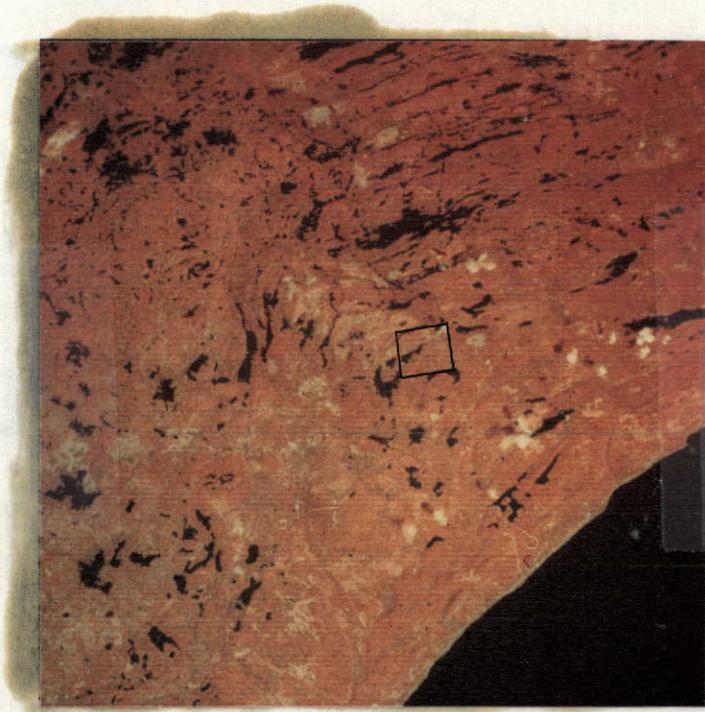
Figure 6. Cook County Study Area and interpretation test unit as seen on color-combined (above) and density level-slice (below) renditions of an ERTS August 12, 1972, scene.

ERTS Products. A considerable variety of products was initially re-
quested for use in this investigation, but 70mm multispectral bulk positive
transparencies proved the most useful - particularly in terms of input to
the I^2S color combiner. Bulk 9 1/2-inch ERTS B&W positive transparencies
were preferred to the precision 9 1/2-inch transparencies for use with the
density level-slicer. The reason for rejecting the latter was the con-
founding of the level-slice process by its "checkerboard" density pattern.

Monitor Screen Photocopy System Development. This involved the
establishment of two camera systems for recording monitor screen displays:
(a) a 35mm camera using extension tubes and bellows, and (b) a bellows-
equipped Hasselblad 70mm camera adapted to produce square format super-
slides. Kodak Hi-speed Ektachrome color reversal film is used to produce
slides for use in the mapping projection system and opaque prints are
produced through the use of daylight Kodacolor negative film with an 80A
color balance filter. The density level-slice color monitor display screen
is copied using Kodak Hi-speed Ektachrome daylight color reversal film
without the 80A filter (see Figures 5 and 6).

Image Projection Screen. The projection screen incorporates flexible
rearview screen material sandwiched between glass, and has proven extremely
useful for viewing, interpreting and mapping (Figure 7). No mirror system
is involved in order to avoid possible light and detail loss; the 2x2 slides
are projected in reversed position with a Carousel projector and viewed
from the opposite side of the screen. A grid transparency is used to align
the projected image on the screen prior to interpretation or mapping. The
bulk of the project's ERTS interpretation and mapping was accomplished on
transparent overlays with this rear screen system.

Establishment of Baseline Ground Truth

Along with proper training and control of the test interpreters,
establishment of reliable baseline ground truth was considered one of the
most important operational phases in the overall study. Annotated overlays
from the 1:60,000 scale color infrared NASA RB57F overflights were used as
the data base against which all ERTS interpretations were eventually checked.
As Douglass and Meyer (5) had previously shown, these photographs permitted
a skilled forest photo interpreter to discriminate extremely well between

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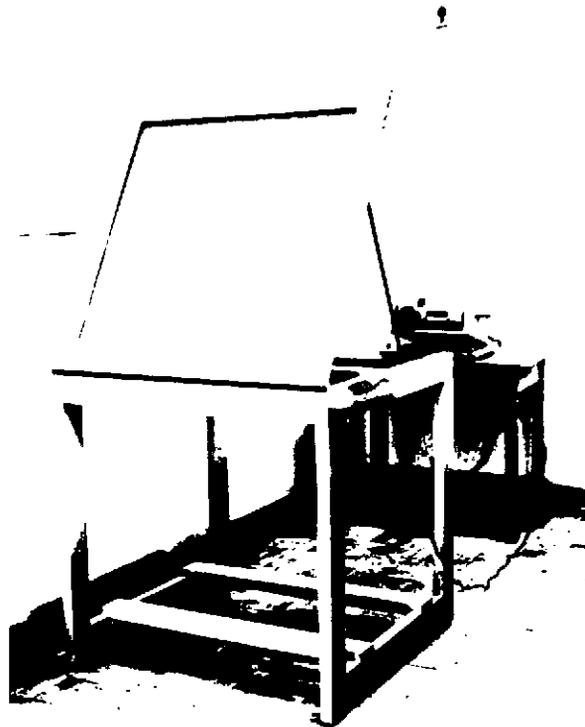
Figure 7. Table-top projection screen and Kodak Carousel Projector holder for interpreting and mapping ERTS-I color combined scenes. Adapted from Aldrich, et al (6).

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the major forest vegetation classes. These base information interpretation overlays were further corrected and verified by a combination of ground checks by IARSL personnel and the use of inventory cover type maps and other data from such sources as the U. S. Forest Service, the Minnesota Department of Natural Resources Division of Lands and Forestry and the Itasca County Land Commissioner's Office.

Development and Test of an Initial Classification System (Scheme A)

On the basis of an exhaustive study of the ERTS imagery, the RB57F underflight photography and the field data of selected sample units in the Chippewa National Forest and Southeast Minnesota Study Areas, two of the investigators developed the classification scheme displayed in Table 2.

This classification scheme was applied and tested by the senior investigator on 4 study units within the Chippewa National Forest Study Area - whose 4 ERTS interpretation overlays and their corresponding ground truth overlays were compared. Each of the 4 study units was 5-10 square miles in size and representative of a particular vegetation/forest land use configuration. Admittedly, this was not a controlled interpretation test in the true sense of the word; however, this was not a problem in that it soon became apparent that an inadequate level of correlation was present between the two sets of overlays - except for a vague matchup of some of the hardwood and conifer areas. In short, it was difficult to assign the various Scheme A forest classes to the color contrasts in the ERTS scenes and to match the delineated class boundaries between the ERTS interpretation overlays and the ground truth overlays.

Development and Test of a Final Classification System (Scheme B)

Since a simpler classification system for ERTS forest interpretation was obviously required, Scheme B (Table 3) was developed. In this arrangement, both the forest classes and the MLMIS land use classes were condensed. A trial application of the scheme was made by the senior investigator to 3 of the 4 study units used in the test of Scheme A and, after his pilot application, each ERTS-derived Scheme B class was compared with its corresponding ground truth overlay to determine what cover type, crown closure and site (upland-lowland) class it contained. Although not conclusive, this pilot comparison suggested that Scheme B was possibly a suitable classification base from which to interpret ERTS imagery.

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Table 2. Forest Vegetation and Land Use Classification Scheme A.

Class	Symbol
Conifers (greater than 75%)	c
Hardwoods (greater than 75%)	h
Mixed (greater than 25% both conifers and hdwds)	m
Highland	u
Lowland	s
High Density (greater than 50%)	"
Low Density (less than 50%	'
--- The following are MLMIS land use classes---	
Cultivated	2
Water	3
Marsh	4
Urban Residential	5
Extractive	6
Pasture and Open	7
Urban Mixed Residential and/or Commercial	8
Transportation	9

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Table 3. Forest Vegetation and Land Use Classification Scheme B
(tested on 4 study units)

Class	Symbol
Conifers	c
Hardwoods	h
Mixed	m
Cultivated, Pasture, or Other Open Land	2
Water	3
Marsh	4
Urban Residential and/or Commercial	5,8
Extractive	6

A controlled test interpretation was next initiated on three study units which had not been included in the previously-described test and pilot comparison. Two experienced aerial photo interpreters, who had not been involved in the ground truth data collection and compilation - and who had no prior exposure to, or experience with, the 3 test study units, were trained in the use of Scheme B on other (similar) study training units - each of which contained samples of the cover types of interest. The senior investigator also participated in the test but his results are not reported here due to his prior close association with some of the ground truth data. It was interesting to note, however, that his results differed little from the two interpreters who had neither prior knowledge or experience in the test study units.

Each test unit was gridded into 10-acre cells; a cell size chosen on the basis of the detectability of woodlots and gravel pits of this size on ERTS MSS Band 5 imagery which had been field-checked in southeastern Minnesota. Every cell in each test unit was classified, thus providing a 100% sample which eliminated any affect of sampling error upon interpretation accuracy.

All interpreters used the overlay which had been especially prepared for each unit interpreted. After an interpreter completed the annotation of an overlay, it was copied, his annotations erased, and the same overlay accurately replaced for the next interpreter by means of several obvious ground control points (primarily water bodies). This insured that each interpreter studied precisely the same ground scene on the projected ERTS image and was not biased by knowledge of the information annotated by his colleague.

Itasca County Forest Map Preparation

At the close of the test of Scheme B, and in order to further examine the applicability of ERTS data to the Minnesota Land Management Information System (MLMIS), an additional study project involving the mapping of Itasca County was initiated. Color-combined slides were projected and interpreted in the same manner as for the Chippewa National Forest Study Area and a classification scheme (Scheme C) employed that was similar to the Scheme B test interpretation scheme, but modified with somewhat different mixed conifer-hardwood categories (see Table 4).

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Table 4. Forest Vegetation and Land Use Classification Scheme C.
(being tested in Itasca County)

Class	Symbol
Conifers (greater than 75% of the cover type)	c
Hardwoods (greater than 75% of the cover type)	h
Mixed (conifers and hardwoods both greater than 25% of the cover type, conifers dominant)	mc
Mixed (conifers and hardwoods both greater than 25% of the cover type, hardwoods dominant)	mh
Open, Pasture, Cultivated	2
Water	3
Marsh	4
Urban	5,8
Extractive	6

On the basis of his prior training and experience with the Chippewa National Forest Study Area tests, the senior investigator proceeded with the interpretation and mapping of the southern half of Itasca County. At the time of the actual interpretation, reliable ground truth was not yet available - which insured the lack of bias in the interpretation product. The resulting ERTS-based forest classification maps are now in the hands of six professional forestland managers, who represent various forest resource management agencies and firms active in the Itasca County study area. The cooperators will evaluate those portions of the ERTS-generated map for which they possess unique knowledge, experience and ground truth data. Following evaluation and correction of the ERTS interpretation of the forest vegetation and land use classes of this portion of the county, the remainder of the county will be interpreted, mapped and evaluated.

DATA ANALYSIS

As previously indicated, the detailed (Scheme A) system of classification proved far too detailed for use with ERTS imagery. Despite the large number of clearly discernible color contrasts (many of them very small) on the project ERTS images, they were found to have very little relationship to actual ground differences in the forest vegetation cover.

The controlled test of the simpler (Scheme B) system of classification of ERTS imagery was also somewhat disappointing, as may be seen in Table 5 and Appendix Table I. Two of the interpretation test units (one within the Chippewa National Forest and the other in the Cook County Test Area) were interpreted with Scheme B categories to an accuracy of only 50%, or less, for all classes employed. This figure was still lower if it was calculated without the "3" (water) class included. The Southeast Minnesota Test Area unit was interpreted to an accuracy level of 75%, according to Scheme B - a somewhat higher level of attainment due to the more homogeneous forest cover (hardwoods) in this area. Interpretation accuracy was, in all cases, significantly higher if the forest cover classes were combined into a single class (see Table 6).

The Itasca County interpretation and mapping project has not reached a point where meaningful data analysis is possible.

Table 5. ERTS Interpretation Test Results for All Classes Using the Scheme B Classification System

| Interpretation test unit | Interpreter | Correct calls | | Errors of omission and commission |
		with Class 3 (water)	without Class 3 (water)	
Chippewa National Forest	A	50%	45%	50%
	B	46%	51%	54%
Southeast Minnesota	A	76%	N/A	24%
	B	74%	N/A	26%
Cook County	A	46%	41%	54%
	B	42%	37%	58%

Table 6. ERTS Interpretation Test Results for the Forest Class Using the Scheme B Classification System

Interpretation test unit	Interpreter	No. of forest ground truth cells	No. cells identified as forest class	Percent accuracy
Chippewa National Forest	A	446	432	97%
	B		429	96%
Southeast Minnesota	A	166	144	87%
	B		104	63%
Cook County	A	341	304	89%
	B		301	88%

CONCLUSIONS

Although ground details under 10 acres in size were identifiable with ERTS imagery, only very broad forest resource features could be reliably discriminated from the particular ERTS spectral slices processed and used in this study. Overall ERTS image details, in terms of the many visible bits of color apparent on the enlarged and color-combined ERTS scenes, suggested a fairly high level of forest cover type identification capability. In actual practice, however, a relatively low degree of relationship existed between these many color bits and specific ground features.

By design, the very detailed nature of the first classification scheme (Scheme A) tested, which used 7 forest classes, was overly optimistic. The final interpretation scheme (Scheme B), however, which was carefully tested on three areas by two interpreters, involved only 3 forest classes - in addition to the non-forest classes. But here too, the best that could be attained was, at the least, the MLMIS's (single) "forest" class.

Possibilities for the extension of this level of forest classification are, however, felt to exist to the extent of the differentiation of conifers from hardwoods in certain instances and/or by specific techniques: (a) prior knowledge of extensive and relatively homogeneous conifer or hardwood forest cover types such as the predominantly hardwood southeast Minnesota forest, or the predominantly spruce-fir-tamarack bog areas of north central Minnesota; and/or (b) the use and manipulation of multi-season combinations of ERTS scenes - e.g., the use of snow enhancement to distinguish the hardwoods from the overall forest-designate area determined previously from growing season imagery.

In summary and for the conditions tested, it can be said that ERTS imagery provided trained, professional forest interpreters with the capability to discriminate the current Minnesota Land Management Information System (MLMIS) "forested" class. Further breakdowns of the forested class were found to be unreliable on the average, but there appear to be possibilities for development of practical techniques which will permit further stratification of ERTS forest scenes into "conifer" and "hardwood" classes. Such approaches are now under study by the Institute of Agriculture Remote Sensing Laboratory.

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ACKNOWLEDGEMENTS

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WORK PLANS FOR FY74

NASA funding for this project was exhausted as of July 1, 1973, and the extent of future progress will depend upon the degree to which funding from other sources will be available and whether this (and most other) ERTS projects will be re-established by NASA at a later date. Therefore, to the extent that funding will be initially available from other sources within the Institute of Agriculture Remote Sensing Laboratory, the following three areas of investigation will be pursued:

1. Completion of the Itasca County Land Use Interpretation Study. Scheduled for completion sometime in the fall of 1973, the results obtained from the field cooperators will provide the basis for the correction of that portion of Itasca County already mapped with ERTS. These findings will form the basis for the next stage of the project: the interpretation and mapping of the remainder of Itasca County and its verification, and preparation of a report on this study phase.

2. Density Level-Slice Enhancement Approaches to ERTS Data Display and Analysis. A closeup bellows attachment on the VP-8 camera will permit analysis of small portions of 70mm bulk B&W positives of the Chippewa National Forest Study Area. Applications of this technique to 9.5-inch bulk transparencies on the Cook County and Southeast Minnesota Study Areas will also be tested.

3. Multi-Season Combination Study. Various seasonal combinations (e.g., winter scene in registration with a spring, summer or fall scene) will be investigated and compared with growing season combinations of the study areas.

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Project: "ERTS-1 Data Applications to Minnesota Land Use"

IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c	50	36		14						50	14	28%	36	72%
hardwood h	195	18	97	74	6					195	98	50%	97	50%
mixed m	200	76	29	88	6	1				200	112	56%	88	44%
open,pasture cultivated 2	50	3	10	10	26	1				50	24	48%	26	52%
water 3	59		1			58				59	1	2%	58	98%
marsh 4	55	13	21	21						55	55	100%	0	0%
urban 5,8	4		2	2						4	4	100%	0	0%
extractive mining 6														
# type indicated		146	160	209	38	60				613	308	50%		
# errors committed		110	63	121	12	2				308				
% commission		75%	39%	58%	32%	3%				50%				

Area   **Chippewa National Forest**

Interpreter   **A**

Appendix Table I

with class #3	305	50%
without class #3	247	45%

APPENDIX

Project: "ERTS-1 Data Applications to Minnesota Land Use"
IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c	51	41	7	1	1		1			51	10	20%	41	80%
hardwood h	197	34	146	14	3					197	51	26%	146	74%
mixed m	198	85	89	12	9		3			198	186	94%	12	6%
open,pasture cultivated 2	51	5	19	1	25	1				51	26	51%	25	49%
water 3	59		2			57				59	2	3%	57	97%
marsh 4	55	12	41				2			55	53	96%	2	4%
urban 5,8	4		4							4	4	100%	0	0%
extractive mining 6														
# type indicated		177	308	28	38	58	6			615	332	54%		
# errors committed		136	162	16	13	1	4			332				
% commission		77%	53%	57%	34%	2%	67%			54%				

with class #3	283	46%
without class #3	226	41%

Area   Chippewa National Forest

Interpreter   B

Appendix Table I

Project: "ERTS-1 Data Applications to Minnesota Land Use"
IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c													--	--
hardwood h	167		144		22			1		167	23	14%	144	86%
mixed m													--	
open,pasture cultivated 2	216		47		162			7		216	54	25%	162	75%
water 3	1				1					1	1	100%	0	0%
marsh 4	3		2		1					3	3	100%	0	0%
urban 5,8	17				15			2		17	15	88%	2	12%
extractive mining 6														
# type indicated			193		201			10		404	96	24%		
# errors committed			49		39			8		96				
% commission			25%		19%			80%		24%				

with class #3	308	76%
without class #3		

Area   Southeast Minnesota

Interpreter   A

Appendix Table I

Project: "ERTS-1 Data Applications to Minnesota Land Use"

IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c													--	--
hardwood h	166		104		61			1		166	62	37%	104	63%
mixed m														
open,pasture cultivated 2	217		16		193			8		217	24	11%	193	89%
water 3	1				1					1	1	100%	0	0%
marsh 4	3		2		1					3	3	100%	0	0%
urban 5,8	17				16			1		17	16	94%	1	6%
extractive mining 6														
# type indicated			122		272			10		404	106	26%		
# errors committed			18		79			9		106				
% commission			15%		29%			90%		26%				

Area ____ **Southeast Minnesota** ____

Interpreter ____ **B** ____

Appendix Table I

with class #3	298	74%
without class #3		

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Project: "ERTS-1 Data Applications to Minnesota Land Use"
IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c	142	73	8	46	12	3				142	69	49%	73	51%
hardwood h	26	1	15	8	2					26	11	42%	15	58%
mixed m	170	69	33	51	17					170	119	70%	51	30%
open,pasture cultivated 2	11	1		2	8					11	3	27%	8	73%
water 3	32					32				32	0	0%	32	100%
marsh 4	11	2		4	5					11	11	100%	0	0%
urban .5,8														
extractive mining 6														
# type indicated		146	56	111	44	35				392	213	54%		
# errors committed		73	41	60	36	3				213				
% commission		50%	73%	54%	82%	9%				54%				

with class #3	179	46%
without class #3	147	41%

Area   Cook County

Interpreter   A

Appendix Table I

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Project: "ERTS-1 Data Applications to Minnesota Land Use"

IMAGE INTERPRETATION TEST RESULTS

ground truth feature	# test cells	Image Interpretation Results												
		c	h	m	2	3	4	5,8	6	totals	# omitted	% omission	# correct	% correct
conifer c	143	17	12	103	8	1	2			143	126	88%	17	12%
hardwood h	26	2	16	5	3					26	10	38%	16	63%
mixed m	172	9	44	93	25		1			172	79	46%	93	54%
open,pasture cultivated 2	11			4	7					11	4	36%	7	64%
water 3	33					33				33	0	0%	33	100%
marsh 4	10			8	1		1			10	9	90%	1	10%
urban 5,8														
extractive mining 6														
# type indicated		28	72	213	44	34	4			395	228	58%		
# errors committed		11	56	120	37	1	3			228				
% commission		39%	78%	56%	84%	3%	75%			58%				

with class #3	167	42%
without class #3	134	37%

Area Cook County

Interpreter B

Appendix Table I

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