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LAND-USE IN IOWA: 1976
AN EXPLANATION OF THE MAP

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ABSTRACT

The staff of the Iowa Geological Survey Remote Sensing Lab (IGSRSL) recently completed a land-use map of Iowa based on manual photo interpretation of LANDSAT I images. The map, the first of its kind for Iowa, was prepared at a scale of 1:250,000 and printed at a 1:500,000 scale. It displays nine categories of land-use; they are urban residential, urban commercial/industrial, urban open, transportation network, extractive land, agricultural land, forest land, water, and reservoir flood pool. Interpretations were verified through the use of Skylab and high altitude aircraft photography. Information from various maps produced by the U.S. Geological Survey, Iowa Department of Transportation, Federal Aviation Administration and the Iowa Geological Survey also aided in production of the map. Preliminary copies of the map were reviewed by each of Iowa's 17 Regional Planning Agencies as well as the Iowa Conservation Commission and Iowa Office of Planning and Programming. These agencies corrected interpretation or handling errors and insured inclusion of major land-use changes that occurred subsequent to LANDSAT image acquisition. A total of 6½ man-months was needed to produce the map at a total cost, from image acquisition through printing, of 18¢ per square mile. The map can provide useful information that may be used in conjunction with other resource data in defining some management goals or policies. This publication is presented to explain the procedures used in the map's production and limitations inherent in the map.

INTRODUCTION

Private citizens, public interest groups, and governmental boards and agencies have expressed an ever increasing desire for information about Iowa's natural resources. In part, this desire has been generated by an increased awareness of the complex nature of the problems relative to management of these resources. Such problems as water pollution, flood protection, highway construction and shortages of energy and food have recently become increasingly significant. The search for the solutions to these problems has lead to the introduction of comprehensive land-use and single resource legislation at both the federal and state governmental levels and to the consideration of more restrictive rules and ordinances at the county and city levels of government.

Land-Use in Iowa, 1976 was produced to provide generalized information on the present utilization of land in Iowa. As the first such map produced in the state, it is intended to provide a synoptic view of the distribution of several categories of land-use within the state which, when used in conjunction with other resource data, may be useful in defining some management goals or policies.

This technical bulletin was produced to provide information on the interpretive and graphic techniques used in producing the map. The problems involved in developing such a map are numerous and in some instances limit the accuracy of the information as mapped. The following pages outline the procedures used to produce the map. It is our hope that this discussion will help map users to assess the value of the information for their specific application as well as provide useful suggestions to those interested in producing similar maps.

Basic Sources of Data

Imagery from the LANDSAT (formerly ERTS) Satellite was the primary source of information used in production of the map *Land-Use in Iowa: 1976*. LANDSAT was chosen because it represented the only available source of imagery that provided statewide coverage which was both current and at a uniform, small scale. These attributes allowed production of an up-to-date map of land-use in Iowa at a workable scale, 1:500,000, using a reasonably small number of images. This makes manual photographic interpretation efficient.

The images used were produced by the LANDSAT Multispectral Scanner System. This system simultaneously acquires four coincident images at discrete spectral bands in the visible and near infrared portions of the electromagnetic spectrum. The four bands are 4,5,6, and 7 which record electromagnetic radiation (EMR) of wavelengths from .5 to .6 microns (what we see as green light), .6 to .7 microns (red light), .7 to .8 microns (near infrared), and .8 to 1.1 microns (near infrared) respectively. The two near infrared bands record EMR of wavelengths slightly beyond the normal sensitivity of the human eye. This portion of the infrared range does not record heat. Heat or thermal infrared EMR is recorded in infrared wavelengths from about 3.5 to 14 microns.

Each of the four bands can be viewed as an individual image with each providing somewhat different land cover information dependent upon seasonality and surface cover. For example band 5 provides the most information on cultural features, particularly on summer images, and band 7 allows the best delineation of surface water. Although individual images are valuable sources of land-use information, they are even more useful when combined as false-color composite images. These images, closely resembling color infrared photographs, are produced by the EROS Data Center in Sioux Falls, South Dakota by coloring band 4 blue, band 5 green and band 7 red.

Nine of these false color LANDSAT images were obtained from the EROS Data Center at a scale of 1:250,000. At this scale one inch on the photograph represents approximately 4 miles on the ground. Figure 1 locates the area covered by the nine images and Table 1 identifies each image. This working scale allowed direct comparison with the U.S. Geological Survey 1 x 2 degree NK series maps. The complete state coverage of the NK series maps provided a valuable base for land-use interpretation from the LANDSAT images. Use of this scale for map production

Fig. 1 Location and Dates of LANDSAT I images used in the production of the Land-Use Map of Iowa

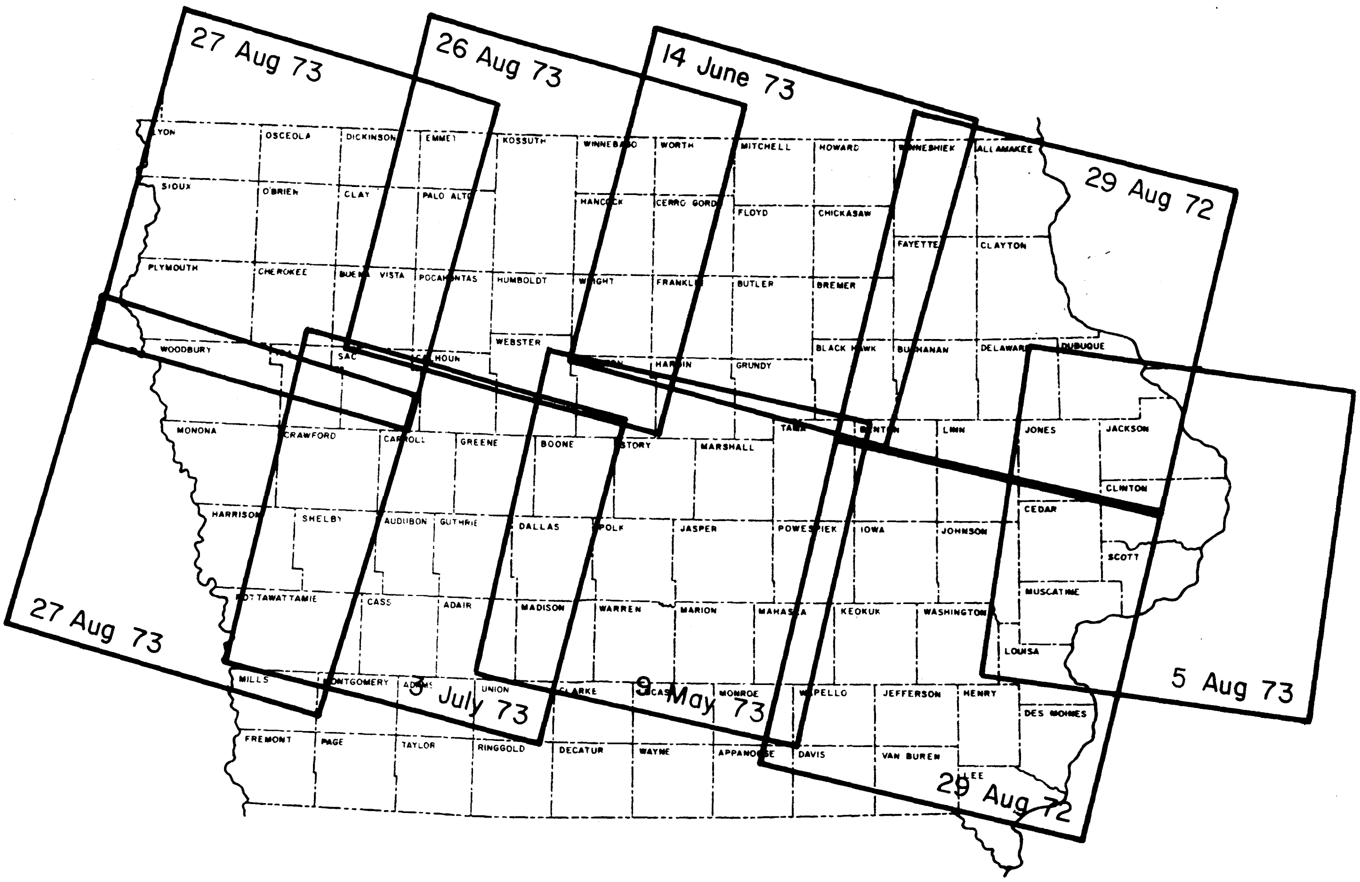

Table 1 LANDSAT Images used for Map Production

Location	Central Town	Date	Identification Number
East Central Ia.	Clinton	5 August 1973	E-1378-16153
Northeast Ia.	Guttenberg	29 August 1972	E-1037-16210
Southeast Ia.	Washington	29 August 1972	E-1037-16213
Northcentral Ia.	Charles City	14 June 1973	E-1326-16272
Central Ia.	Ames	9 May 1973	E-1290-16280
Northcentral Ia.	Algona	26 August 1973	E-1399-16320
Southwest Ia.	Audubon	3 July 1973	E-1345-16331
Northwest Ia.	Paullina	27 August 1973	E-1400-16375
Westcentral Ia.	Onawa	27 August 1973	E-1400-16381

allowed a 50% reduction for the completed, printed version of the map at 1:500,000 scale. Such reduction enhances the appearance of drafted maps.

Uniformity of information across all designated images and the land-use information desired were the criteria used in choosing the land-use categories to be mapped. The images were acquired with zero or minimal cloud cover between August of 1972 and August of 1973. Where available, summer images were used because they were determined to provide the most satisfactory land-use data.

As can be seen in Figure 1 the southernmost counties in central and western Iowa were not covered by acceptable LANDSAT imagery. To map land-use in these areas 1:80,000 scale color infrared aircraft photography was used. This photography was obtained by the Iowa Geological Survey in cooperation with the U.S. Soil Conservation Service during the spring of 1975. Figure 3 provides a map of the area covered by this photography.

Other photographic and non-photographic sources of land-use information were utilized to verify LANDSAT interpretations. All of those sources, their uses and references are listed in Table 2. Three photographic sources in addition to LANDSAT and IGS-SCS photography were used to double-check land-use classification. Photos obtained by the Skylab S-190B camera in 1973 and 1974 were used to check interpretations in much of the state (see Figure 2). These photos were natural color and were used at scales of 1:950,000, 1:500,000 and 1:150,000.

TABLE 2

Data Sources for Land-Use Map Production

DATA	USE	SOURCE
Photography		
LANDSAT 30" x 30" color enlargements (1972-75) Scale: 1:250,000 (see figure 1 for frame numbers and coverage area)	general land-use mapping	EROS Data Center Sioux Falls, S.D.
NASA Skylab Photography (1973-74) Scales: 1:2,800,000 and 1:950,000 (see figure 4 for coverage area)	used to check LANDSAT interpretations	EROS Data Center Sioux Falls, S.D.
IGS-SCS High Altitude Southern Iowa River (1975) Basin Study Photography Scale: 1:80,000 (see figure 2 for Coverage area)	mapping regions of Southern Iowa not mapped from LANDSAT--also used to verify LANDSAT interpretations	Iowa Geological Survey Remote Sensing Lab Iowa City, Iowa
NASA Cornblight Photography Scale: 1:120,000 (1972) (see figure 3 for coverage area)	used to check LANDSAT interpretations	EROS Data Center Sioux Falls, S.D.
NASA High Altitude Des Moines (1973) to Omaha Flight Scale: 1:120,000 (see figure 4 for coverage area)	used to check LANDSAT interpretations	EROS Data Center Sioux Falls, S.D.
Non-Photographic Data		
U.S.G.S. 1:250,000 scale N.K. Series Maps; NK 14-3, 14-6, 14-9, and NK 15-1 through 15-12	used to prepare county outlines on base map; verify city, highway, river, railroad, and reservoir location	U.S. Geological Survey Iowa City, Iowa
1975 Official Highway Map of Iowa Scale: 1:825,000	used to verify city location and size and highway location	Iowa Department of Transportation Ames, Iowa
Current Inventory & Transportation Map of Iowa (1974) Scale: 1:1,580,000	used to identify and locate principal railroads & airports	Iowa Department of Transportation Ames, Iowa
Sectional Aeronautical Charts, Omaha and Chicago Scale: 1:500,000	used to locate and identify principal airports	Federal Aviation Administration Local Airports
Iowa Highway Commission County Highway & Transportation Maps, Scale: 1:250,000	used to locate and identify towns, roads, & extractive facilities	Iowa Department of Transportation Ames, Iowa
Mineral Resources of Iowa Scale: 1:500,000	used to check extractive facilities	Iowa Geological Survey Iowa City, Iowa

Another source of verification photography was 1:120,000 scale color infrared photography obtained by high-altitude NASA aircraft in the summer of 1971 as a part of a NASA corn leaf blight study. A map of the areas covered by the corn leaf blight study photography is reproduced in Figure 4. The final source was 1:120,000 scale color and color infrared photography obtained in the fall of 1973 by NASA between Des Moines and Omaha (Figure 5).

Non-photographic data was also utilized extensively in the production of the map of *Land-Use in Iowa, 1976*. This data was in the form of pre-existing maps. As previously mentioned the U.S. Geological Survey NK-Series maps were used to provide base control. Other references include the *1975 Official Highway Map of Iowa, the Current Inventory and Transportation Map of Iowa, Sectional Aeronautical Charts of Chicago and Omaha, General Highway and Transportation Maps* and a map of the *Mineral Resources of Iowa*. More information on these maps, their uses and references is listed in Table 2 and is detailed later in this report.

LAND-USE CATEGORIES

Nine land-use categories were designated to be identified and mapped (see Table 3). With few exceptions the categories chosen were those which were readily identifiable on all the LANDSAT images used. One exception was

Table 3 Land-Use Map Categories

1. Urban Residential
2. Urban Commercial/Industrial
3. Urban Open
4. Transportation Network
5. Extractive Land
6. Agricultural Land
7. Forest Land
8. Water
9. Reservoir Flood Pools

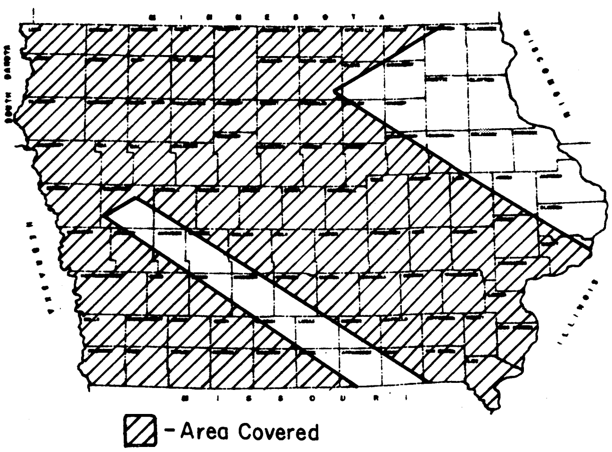

Figure 2: Skylab coverage of Iowa.

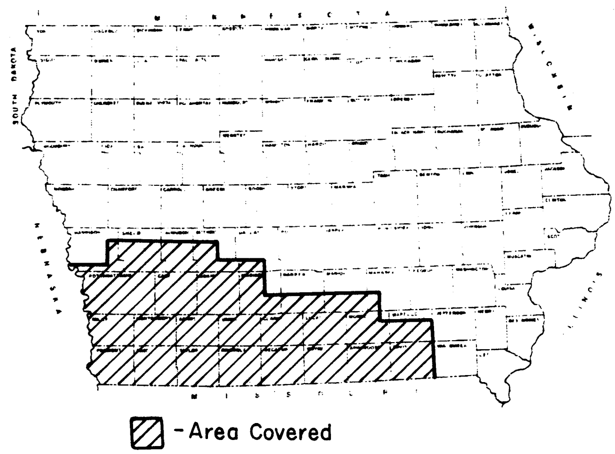

Figure 3: Area covered by IGS-SCS High Altitude Photography, 1975.

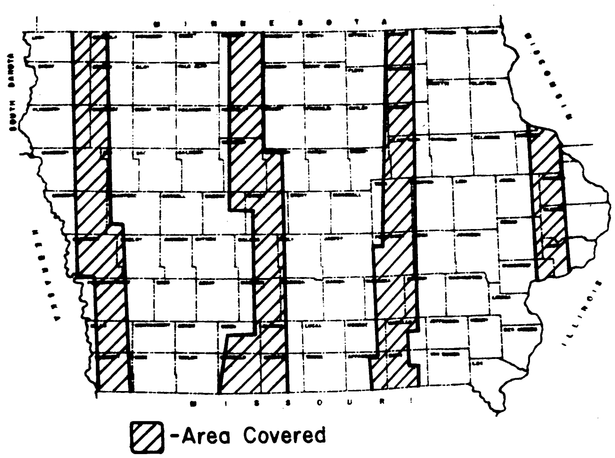

Figure 4: Area covered by NASA Cornblight Photography, 1971.

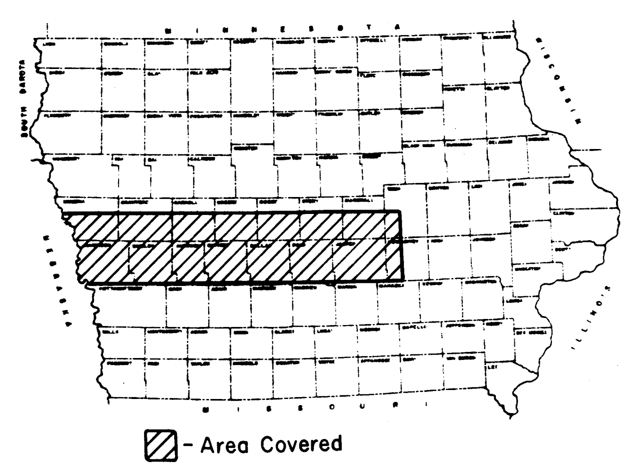

Figure 5: Area covered by NASA Des Moines-Omaha Flight, 1973.

the location of flood pools associated with Iowa's four major reservoirs. These areas were not identifiable on the imagery because the pools were not full when the images were produced. The maximum pool locations were determined using information supplied by the U.S. Army Corps of Engineers at Rock Island and the U.S.G.S. N.K. series maps.

PRODUCTION OF THE MAP

The actual production of *Land-Use in Iowa, 1976* was accomplished by human interpretation of the 30" x 30" LANDSAT color infrared images followed by repetitively cross-checking interpretations against various other data sources, including data provided by regional planning agencies. Mapping was done in ink on overlays of K & E 44 1035 stabilene ink-surface film. The first step in this process was to map the county lines on the overlay within the limits of the image being interpreted. This was accomplished by locating key roads and intersections near county lines on Iowa Highway Commission *General Highway and Transportation Maps* and on the images. Then using these landmarks the county lines were mapped on the overlay. The presence of the county lines assisted photo interpreters in locating particular land-use areas to be verified from other maps.

All federal highways and selected state highways were then added to the overlay. They were located by using the U.S.G.S. 1:250,000 scale NK series maps as a base. These locations were then verified from the LANDSAT images. Where disagreements occurred the LANDSAT locations were used. Normal pool and flood pool levels of Iowa's four major reservoirs were also added to the overlay at this time. Information from both LANDSAT and the NK series maps was used for this purpose.

Interpretation and mapping of the remaining land-use categories (forest, extractive facilities, water, airports, and urban residential, commercial and industrial, and urban open) were then completed from each LANDSAT image.

To facilitate mapping land-use from LANDSAT images, the interpreters began with areas with which they were somewhat familiar. This allowed each interpreter to gain skill at identifying the spectral reflectance characteristics of each of the various land-use categories.

Features mapped as towns and rivers were verified from the *General Highway and Transportation Maps* and NK series maps, with the latter being used to locate rivers where they became unidentifiable on the images. Airports were checked against the *Sectional Aeronautical Charts* to verify location, runway composition, and size. Features identified as extractive facilities were verified from the *General Highway and Transportation Maps*, NK series maps, and the map of *Mineral Resources of Iowa*. A final in-house check of the interpretation was accomplished by examining all available high altitude and Skylab photography to verify the interpretations from the LANDSAT imagery. Railroads were added later using the *Current Inventory and Transportation Map of Iowa* and the NK series maps for location.

The next step in the production of the map of *Land-Use in Iowa, 1976* was the transfer of interpretations from the overlays to a 1:250,000 scale base. The base consisted of 12 individual maps. Each map included a grouping of counties chosen so the areas of each map were nearly equal and their physical size would allow easy duplication by the Geological Survey's Diazojet Mark III Whiteprinter. Figure 6 shows the multi-county groupings of each base map. The transfer of information to the base maps was done township by township in order to correct for minor variations between the scales of the LANDSAT images and the base maps.

The area of southwest and south central Iowa not covered by good quality LANDSAT color composites (see Figure 1) was mapped by interpreting land-use information on the 1:80,000 scale, 1975 IGS-SCS color infrared photography (Figure 3). This information was transferred directly from the photography to the ozalid copies of the base maps, using available U.S.G.S. topographic maps for control. The IGS-SCS imagery provided increased resolution and therefore greater land-use information than the LANDSAT imagery. For uniformity, the data was generalized to match the level of detail obtained by LANDSAT interpretation.

After transfer of the information to base maps, black-line ozalid copies of each map were produced, with the various land-uses color coded with Prismacolor pencils. The colored ozalid prints were then regrouped by counties to correspond with the areas included in Iowa's

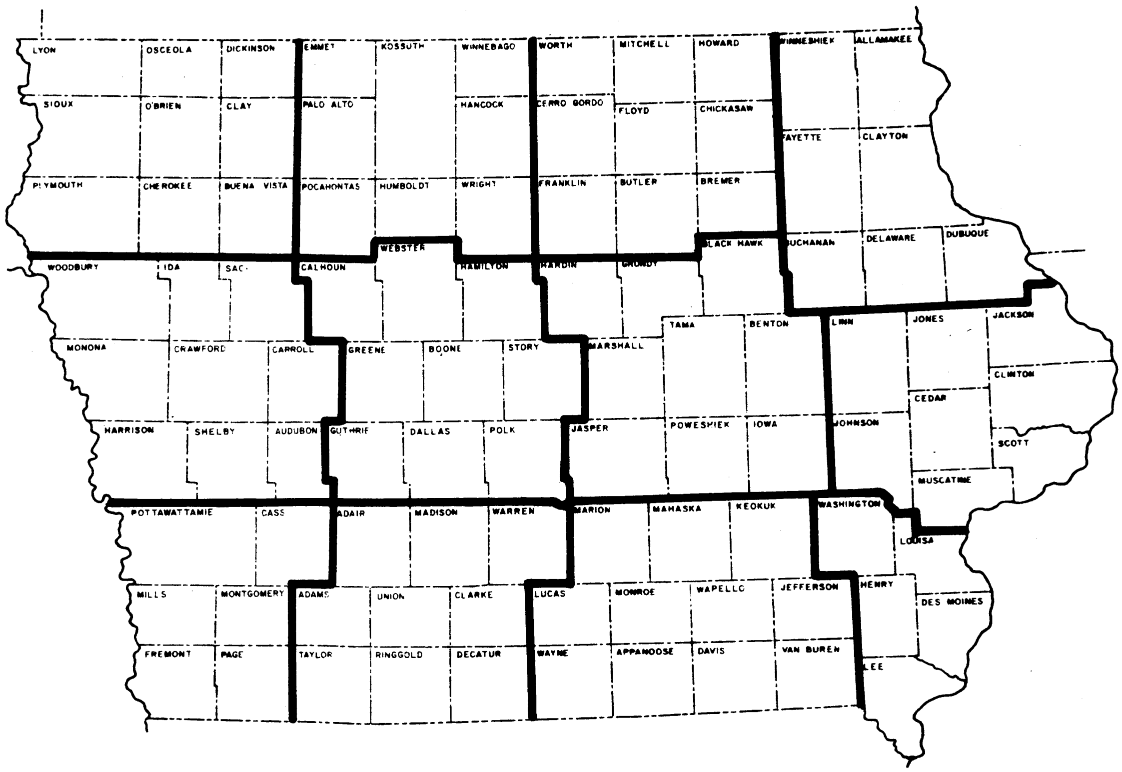

Fig. 6 Multi-county groupings used Land-Use map Production

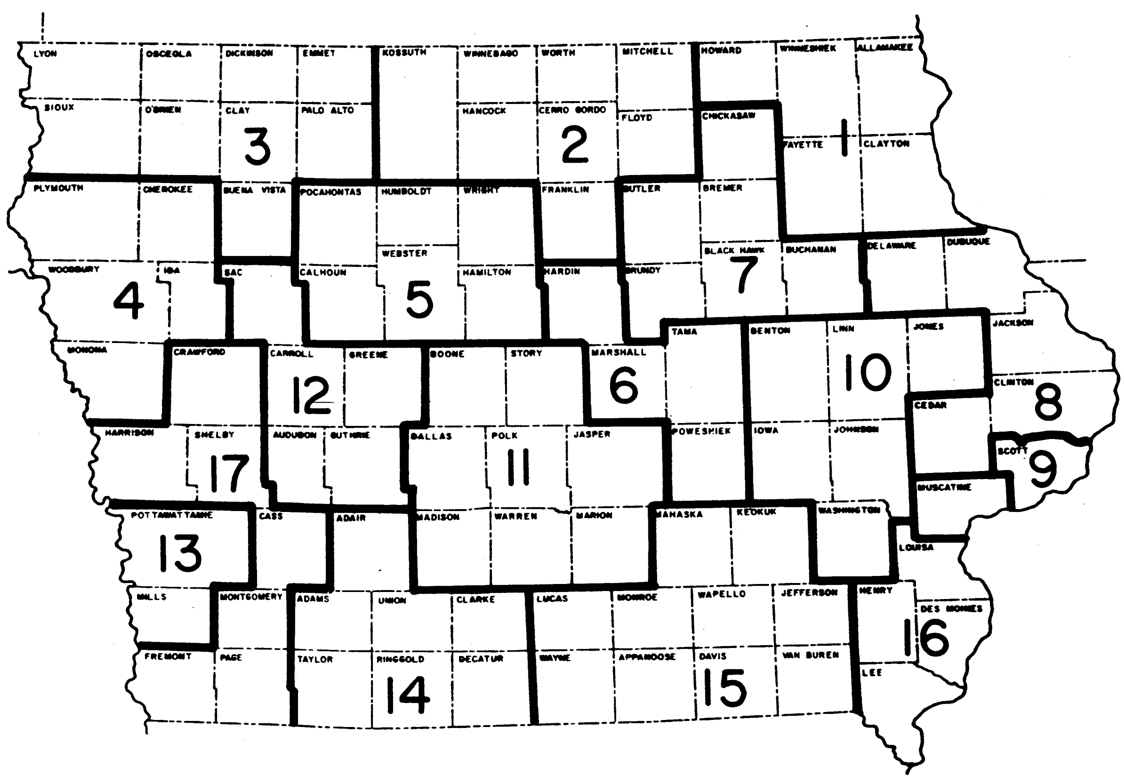

Fig. 7 County groupings for Regional Planning agencies

multi-county regional planning agencies, and a copy of the land-use interpretation was mailed to each agency for additions, corrections, and comments. Figure 7 outlines the county groupings of Iowa's regional planning agencies. Of the 17 agencies, 14 returned the maps with corrections and suggested changes. Those suggestions consistent with the purpose and limitations of the map were adopted and the appropriate changes were made. The finished maps were then drafted to produce camera-ready copy, i.e. registered overlays from which the printer could directly burn negatives without the costly process of producing color separations. These were then forwarded to the printer for production of the final map.

Identification of Land-Use from LANDSAT Images

Because none of the eight land-use classifications interpreted from the LANDSAT imagery produced a unique, visual spectral response on the color infrared composites, a number of factors had to be considered in identifying the land-use of any given area. Some of the factors considered were color (hue and saturation), shape, size, and association with other features. The following describes many of the parameters used to identify each land use as well as some of the possible problems in interpretation associated with each.

1. Urban Residential. Three classes of urban land-use are differentiated on the map of *Land-Use in Iowa: 1976*. These are residential, commercial/industrial, and open land.

On the LANDSAT color infrared images developed, urban areas appear in flesh-colored tones, with white and/or soft blue mottling present in larger cities. Their identification is often aided by their location at the hub of a radiating road network.

Urban residential areas dominated by single family dwellings produce a flesh to pinkish coloration on the LANDSAT imagery, resulting from the integration of white tones produced by such high reflectance objects as houses, roads and driveways, and red tones produced by the high reflectance of infrared EMR by trees, lawns and other vegetation. The classification of a particular reflectance as a residential area is a generalization because such areas may contain small businesses and even light industry. However, they are predominantly residential.

The August imagery has proved to be the best for differentiating urban residential areas. They can be easily mapped at this time of year due to their contrast with the more uniformly red colors produced by surrounding croplands and other heavily vegetated areas. Much of the urban vegetation is stressed by lack of moisture, mowing and other urban influences. This stress combined with the integration of white light from the previously mentioned highly reflective objects reduces the intensity of the red tones of urban vegetation as compared to most rural vegetation. The only features which may be confused with urban areas at this time are large areas of sparsely vegetated, well-drained (usually sandy) soils. Such areas are generally found only near major rivers.

Identifying urban areas on the May and June images has proven to be more difficult. At this time the vegetation within urban areas is especially vigorous, reflecting highly in the near infrared. This produces a bright red and white mottled appearance on the LANDSAT prints which is very similar to the response produced by the combination of forestlands, grasslands, and well-drained soils often found in drainages near urban areas.

Low density urban residential areas may be erroneously omitted from this classification. This omission is the result of large green spaces and associated high reflectance of EMR in the infrared wavelengths. Such areas can be easily misidentified as forest or urban open.

2. Urban Commercial and Industrial. Once an urban area has been identified, commercial and industrial areas can be differentiated based on their responses on the color infrared print. Two types of responses are common. Older commercial or industrial areas appear as bluish colors often ringed by a white aureole. The blue colorations are produced by the limited reflectance from the asphalt roofs of older buildings, with the tone of blue dependent upon the amount of white contributed by high reflectance features such as streets, parking lots, etc. between the buildings. The more white present, the lighter the blue tones.

The white aureole is produced by the high reflectance features surrounding the complexes.

Newer industrial complexes and commercial facilities commonly use more modern roofing practices and are almost always associated with large parking lots. These produce a bright white response within the urban areas on the LANDSAT prints due to their high levels of non-selective reflection of incident EMR.

These high reflectance industrial and commercial areas may be confused with other large features with similar high reflectance characteristics. Such land-uses as sand and gravel pits, quarries, and certain large, well-drained, bare soil areas as well as such urban features as high density residential areas, large apartment complexes, and institutions may be misinterpreted as commercial and industrial. Other industrial or commercial facilities of smaller size, dispersed among other land-uses or well landscaped with vegetation, may be misidentified as urban residential.

3. Urban Open. The final urban classification, urban open, includes extensively vegetated areas, such as parks, within urban areas. The more natural settings of these parklands tend to promote healthier vegetation than is found in other urban situations. Some reduction of urban stress and much less highly reflective material create a brighter red response, similar to that produced by non-urban vegetation, which was mapped as urban open when

located within an urban area. There is little chance of confusing this land-use with another. In some cases, however, low density, heavily-wooded residential land may be confused with urban open. Agricultural land surrounded by urban areas could also be confused with urban open land use, but these are rare situations.

4. Transportation Network. Three major transportation systems were included on the land-use map: highways, railroads, and airports. All three are represented on the map by only a selected portion of the facilities actually present.

All federal highways and selected state highways were mapped. Although the transportation network in Iowa represents a significant land-use in Iowa (over 3% of Iowa land is utilized as roads or rights of way)[1], only this portion was included on this small scale map, primarily as an aid in the location of specific areas on the map. The decision to map all federal highways, and only key state highways in areas not served by the federal roads, allows a relatively uniform distribution of roads across the state without de-emphasizing other land-uses.

Identifying selected highways can be difficult. The August images proved optimal in identification of the road network in Iowa. The responses produced on August LANDSAT images by this network were off-white to yellow linear features. The large number of section line roads in Iowa create a striking, square, grid-like geometric pattern over the majority of the state. Only in the high relief areas of southern and northeastern Iowa is this grid absent. Because of this large network of roads, and the difficulty in differentiating between concrete, asphalt, and gravelled roads on LANDSAT imagery it was necessary to work closely with the U.S.G.S. 1:250,000 scale maps, state highway maps, and regional planning agencies in order to assure that the proper roads were mapped. The road network is much less distinct on the spring images. However, at this time paved roads display a slightly greater reflectance than the gravel roads. Even so, it was necessary to use supplementary highway maps when interpreting spring imagery.

At the request of many of the state's Regional Planning Commissions, principal railroad routes as chosen by the Iowa Department of Transportation were also included on the land-use map. Although the actual railroad right-of-ways can only rarely be seen on the LANDSAT images, their diagonal trend breaks up the rectangular pattern of agricultural land. This effect leads to relative ease in mapping railroads in the state. The U.S.G.S. 1:250,000 scale maps were used to aid in locating the railroads where the routes were not identifiable on the imagery.

Paved airport runways were easily identifiable on all LANDSAT imagery used for this project. They, like the roads, are excellent reflectors of visible and near infrared EMR and therefore, have an off-white apperance on the imagery. They are relatively short in length and often oriented in a northwesterly or northeasterly direction. Because of the relative abundance of aircraft landing strips around the state, both public and private, it was decided to include only public airports with hard-surfaced runways of at least 1500 feet in length. This decision allowed use of Federal Aviation Administration Sectional Aeronautical Charts to confirm the locations of airport as interpreted from the imagery.

5. Extractive Land. Extractive facilities, including quarries, sand and gravel pits, and recent borrow pits, are characterized by a high reflectance of incident electromagnetic radiation. On the LANDSAT images these facilities have a very bright white response because of the highly reflective and non-selective nature of the interaction of such materials with EMR. Once the interpreter becomes familiar with this response, they can usually be differentiated from other land-uses. There are, however, other responses which may be confused with these extractive facilities. Very dry, and well-drained soils which have not been recently disturbed often produce a similar white response on the imagery. Urban commercial and industrial areas with newer buildings and large parking lots also produce this white response as do new housing developments and trailer courts. Generally the white produced on the image is seldom as intense as that produced by an extractive facility.

Perhaps the land-use most easily confused with extractive land is large cattle feed lots. The many buildings, use of concrete surfaces, and compaction of bare soil by the cattle create a high reflectance situation very similar to an extractive facility.

Several features of extractive land aid in its identification. Sand and gravel pits are commonly found in association with streams. High reflectance in such locations, especially when vegetation is vigorous, may be mapped as extractive land with a high degree of certainty. Recent borrow pits, areas where materials have been removed for construction, are most frequently found along major highways, particularly interstate highways. Thus reflectance areas directly associated with such highways, and not associated with urban areas, have a high probability of being borrow pits. In identifying quarries, the presence of a flooded portion and its associated blue (highly turbid) water reflectance may be a helpful clue to their identification.

Coal strip mines, also mapped as extractive, have a much different response. On the LANDSAT images they have a grayish-blue coloration very similar to the older commercial and industrial areas discussed. The tones of the strip-mined areas range from almost black to light blue and often display a white aureole. The grayish-blue tones are produced by the black shale and other rock materials which are devoid of vegetation. Strip mines are very easily confused with bare, poorly drained soils. Thus they are often impossible to identify on spring or fall imagery where bare fields are common. On the August imagery, however, the strip-mined areas may be easily spotted and identified because of the high contrast between the vegetated fields and unvegetated mining areas.

6. Agricultural Land. The vast majority of the area mapped as agricultural land is utilized in agricultural related endeavors, such as row crops, cover crops, pasture land, and farmsteads. Many other land-uses, however, also exist in these areas. These include such uses as non-pasture grasslands, scrub land, roads and right-of-ways, very small or low density residential areas, and small ponds and wooded areas. The failure to display these land-uses is not an attempt to minimize their importance. They have not been differentiated on the map because of the inability to accurately interpret them with uniform accuracy over all of the LANDSAT images studied, and the difficulty in displaying them on the small-scale final map.

Row crops, primarily corn and soybeans, are planted in the spring, usually in middle and late May, respectively, and cover over 70%[2] of Iowa's agricultural land. Areas devoted to row crops can be identified on the May and June images as colors of dark to light grayish blue-green. These areas are bare ground, plowed either in the spring or the previous fall. The more recently plowed fields usually appear darker than those plowed earlier because of greater surface roughness and greater surface soil moisture. Rough ground scatters sunlight, reflecting a lower percentage back to the detectors on the LANDSAT I. Rain, wind, and other erosive forces act to smooth these fields with time, increasing their reflectance and changing their appearance on the color infrared composite to lighter tones of grayish blue-green. The amount of soil moisture present also affects the tones of bare soil areas. Water, whether as standing water or soil moisture, absorbs a very large percentage of the incident infrared EMR. This makes poorly drained areas with higher soil moisture appear as darker tones. Conversely, better drained fields have lower soil moisture and reflect a greater percentage of incident EMR to the satellite. This produces lighter tones on the imagery.

The grayish blue-green color is attributable to the general brown to black color of Iowa soils. Brown is produced by combining reflection of EMR of red light wavelengths with a lesser amount of green wavelengths. When the green reflectance is colored blue and the red is colored green as they are in producing color infrared images, blue to green-blue color is produced. The intensity of the reflectance of these colors and the amount of infrared light reflected controls the tone of the response.

On the July image those row crops planted early in the growing season have germinated and grown to the extent that they can no longer be differentiated from cover crops by a human interpreter. This is also true in August although the Purdue University Laboratory for Application of Remote Sensing has successfully used computer analysis to differentiate corn, beans, and other crops using early August LANDSAT imagery.[3] Such computer manipulation of imagery requires sophisticated equipment and technology and was not considered necessary for a general land-use analysis.

Cover crops, primarily winter wheat, oats and hay crops, constitute about 10.5%[4] of Iowa's agriculture land. Winter wheat is planted in the fall and emerges early in the spring at about the same time as hay crops, pastures, and non-pasture grasses. All of these vegetation types appear bright red on the color infrared LANDSAT composite images used and could not be differentiated by visual analysis.

Some differentiation of these agricultural land-uses is possible under ideal conditions. For example, heavily grazed pastureland can sometimes be identified, especially in times of drought, by the lower infrared reflectance of the grazing-stressed grasses. Similarly, for a few weeks subsequent to mowing, hay crops can be differentiated by their lower infrared reflectances. Both of these conditions occur at random times, therefore, no single image is adequate for mapping either land-use without serious omission errors.

7. Forest Lands. The classification of forest land includes all identifiable wooded areas except those within urban areas or reservoir flood pools. Generally wooded areas of 10 acres or larger could be identified; however,

this varied with forest location, season, and image quality. Forested areas, like other concentrations of vegetation, reflect very highly in the infrared portion of the electromagnetic spectrum giving them a red appearance on the LANDSAT color infrared composite images. The red of these forests is a darker red than that produced by crops, pasture or non-pasture grasslands. In some instances, however, particularly on the springtime images, patches of forested land can easily be confused with individual vegetated fields. Also, the ability to differentiate between forest and non-forest vegetation is reduced as image quality deteriorates towards the edges of some images. Midsummer and snow-covered winter scenes provide the best definition of these forested areas.

In Iowa the location and shape of many forested areas assist in their interpretation. They usually occur as irregularly shaped patches and frequently border drainageways. However, many of the thin gallery forests along drainages were not mapped because of difficulties in identifying or mapping them at the small map scale used.

8. Water. Reservoirs, lakes, ponds, and rivers have been classified as water on the land-use map. Iowa has four major reservoirs: Coralville, Rathbun, Red Rock, and Saylorville. The areas of these reservoirs mapped as water are the recreational pool level of each as determined from information obtained in part from Corps of Engineers and the 1:250,000 NK series maps. It was necessary to use this

supplemental data because on the August 1972 image of southeastern Iowa, both the Coralville and Rathbun Reservoirs are at abnormally high levels, as is the Red Rock Reservoir on the May 1973 image of central Iowa. The new Saylorville Reservoir was not yet filled when the map was published but was also mapped at its designed recreational pool level.

All lakes and larger ponds which could be identified on the LANDSAT images have been mapped. The minimum resolvable size varies from image to image depending on season and pond location. Five acre and larger ponds can be identified on the August imagery, but few ponds or lakes smaller than 50 acres can be identified on the May and June images.

This inability to distinguish water in the springtime images is primarily due to the similar responses of water and moist, bare soil. Clear water absorbs a very large percentage of the incident near infrared EMR. This, combined with water's low reflectance of red and green EMR, creates a black response on infrared images. The response goes from black to blue with increased turbidity in the water. Bare soil, especially if it is moist or freshly plowed, also produces a black to dark blue response. Therefore, smaller water bodies surrounded by moist, bare soils are difficult to identify because of the reduced contrast. However, smaller water bodies surrounded by materials with a higher reflectance can often be mapped because of increased contrast. Such situations occur where lakes are ringed with trees or grass or, in the case of quarries or gravel pits, where rock is exposed surrounding the open water. Many quarry-associated ponds are very highly turbid with rock flour. This leads to brighter blue coloration of the water's response and aids in its resolution.

Rivers were also often difficult to identify. Where there is no significant vegetative border in springtime images, the rivers are often not differentiable from bare soils. On the August images the canopy effect of trees growing along narrower rivers often obscures them. Because of these problems, locations of some sections of the rivers mapped on the land-use map were obtained from the U.S.G.S. 1:250,000 scale maps. All information derived in this manner was overlain on the images to correlate locations as closely as possible. Because of these interpretation difficulties it was arbitrarily decided to map all streams identified as rivers on the U.S.G.S. maps and to exclude creeks irregardless of their discharge.

9. Reservoir Flood Pools. Reservoir flood pools are those areas of land inundated when a reservoir is at maximum capacity.

The land included in these flood pools is owned by the Federal Government and controlled by the Corps of Engineers. It is intermittently flooded, sometimes for prolonged periods, but some areas are leased to farmers for raising crops when possible. These flood pool areas may also contain forests and are frequently used as recreation areas during times of lower water levels. However, since the flood pool represents the restricting factor in determining land-use in these areas, other possible uses have not been mapped. The boundaries of all four reservoir flood pools displayed on the map were determined from information provided by the Corps of Engineers and U.S.G.S. 1:250,000 NK series maps. This was necessary because none of the reservoirs were at their maximum pool levels when imaged by LANDSAT.

Map Limitations

Even though many techniques were employed to reduce errors during the production of the map *Land-Use in Iowa: 1976* undoubtedly some mistakes or misinterpretations are present. However, the use of many sources of data to verify LANDSAT interpretation and the final inspection by the state's regional planning agencies has minimized these errors. Most of the possibilities for error or misinterpretation have been discussed in detail throughout this text. Some registration problems in printing have shifted geographic locations slightly on portions of the map, and a few outlined land-uses were left uncolored due to printer error.

The lack of an accurate base of comparison hinders the determination of map accuracy.

To date only a minimal number of errors have been identified on the map. The staff of the Iowa Geological Survey Remote Sensing Laboratory feel that, as a regional interpretation, the map of *Land-Use in Iowa: 1976* represents an accurate portrayal of the utilization of land in Iowa.

CONCLUSION

The Land-use Analysis Laboratory at Iowa State University in Ames, Iowa, has digitized the map of *Land-Use in Iowa: 1976* and subsequently analyzed the map to determine the area consumed by each land-use category and the percent of the total area of the state represented by each. Table 4 displays these areas and percentages.

TABLE 4- Areas Consumed By Mapped Land-Use In Iowa

Land-Use	Area		Percent of Total State
	Acres x 1000	square miles	
Urban Residential	388.3	606	1.1
Urban Commercial/ Industrial	70.6	110	0.2
Urban Open	35.3	55	0.1
Transportation Network[1]	35.3	55	0.1
Extractive Land	35.3	55	0.1
Agricultural Land	32,123.0	50,192	91.0
Forest Land	2,259.0	3,530	6.4
Water[2]	317.7	496	0.9
Reservoir Flood Pool	105.9	165	0.3
Total State	35,370.4	55,264	100.2%

1. Transportation Network figures include airports only

2. Inland rivers are not included in Water figures. The figures include only the Mississippi and Missouri Rivers, Lakes and Reservoirs.

Because of the difficulty in clearly portraying thin, linear features such as railroads, highways, and most rivers to scale on a small scale map such as the map of *Land-Use in Iowa: 1976* and the inaccuracies involved in digitizing such features, they were not included in the Land-Use Analysis Laboratory's area percentages. Information on the land area used by these features can be obtained from the Iowa Department of Transportation[5] and Iowa Conservation Commission.[6]

Land-Use in Iowa: 1976 was produced in a relatively short time and at a low cost. Map interpretation time, including actual interpretation and checking with other available imagery and maps, averaged about 5 man-days per area for each of the 12 multi-county groupings used for the map production (Fig. 6). Another 2½ man-day per area was needed for transferring, corrections, and other changes; this totaled about 90 man-days of interpretation. The nine 30"x30" enlargements of LANDSAT images used were obtained at a cost of $40.00 each from the EROS Data Center, and one roll of mylar and ozalid paper was used. The combined cost for producing the photointerpreted map was $4910.

An estimated 40 man-days was needed by the drafting department to produce camera-ready copies of each of the 12 area maps. Six rolls of mylar were used in the final drafting, and including the drafting pen points consumed, the total drafting costs were $1870.

The cost to print 2700 copies of *Land-Use in Iowa: 1976* totaled $3398. The total cost of production of the map was $10,178.

REFERENCES CITED

1. - Iowa State Highway Commission, 1975, "The Highway Mode: Principal Routes as Proposed, June 1975": Iowa State Highway Commission, Ames, Iowa, p.15-17.

2. - U.S. Department of Agriculture, Statistical Reporting Service, Jan. 1976, "Crop Production".

3. - Bauer, Marvin E. and Cipra, Jan E., 1973, "Identification of Agricultural Crops by Computer Processing of ERTS MSS Data", LARS Information Note 030173, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, 9 p.

4. - U.S. Department of Agriculture, Statistical Reporting Service, Jan. 1976, "Crop Production".

5. - Iowa State Highway Commission, 1975, "The Highway Mode: Principal Routes as Proposed, June 1975": Iowa State Highway Commission, Ames, Iowa, p. 15-17.

6. - Iowa Conservation Commission, 1975, "Land and Waters Under Jurisdiction of the Conservation Commission" Des Moines, Iowa.

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