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Applications of aerial imagery in identification of natural areas

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University of Northern Iowa

APPLICATIONS OF AERIAL IMAGERY IN IDENTIFICATION OF NATURAL AREAS

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Kendall Duane Wessel

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ABSTRACT

There is current interest in utilizing aerial imagery to obtain information on natural vegetation. The purpose of this study is to utilize and evaluate commonly available aerial imagery to identify potential natural areas suitable for preservation and to initiate development of a procedure for imagery interpretation to meet this goal.

Clayton County, located in the northeastern quarter of the state of Iowa, was selected for study because it is dissected by steep, narrow stream valleys that are unsuitable for cultivation and may still possess native vegetation of a quality suitable for preservation.

Baseline or control communities were selected from known natural areas because of their: (1) representative vegetation associations, (2) diversity of species, (3) varied topography, and (4) worthiness of preservation. All control site vegetation was ground surveyed utilizing density plot samples to determine species density, diversity, community structure, and habitat quality. This information was correlated with aerial imagery to establish photographic signatures.

Potential natural area communities were selected on the basis of their photographic similarity to the controls. Potential sites were then similarly ground surveyed to verify their imagery signatures.

Imagery utilized were high altitude color infrared transparencies from the Iowa Geological Survey, and low altitude normal color transparencies and black-and-white panchromatic contact prints from the Agriculture Stabilization and Conservation Service and Soil Conservation Service. The majority of this imagery had consistent image quality. Only color ASCS transparencies displayed tonal variation and quality loss. Species identification was not practical in most situations due to insufficient resolution. Individual trees and canopy textures were resolved as well as prairies as small as one acre and with some good texture qualities. Simultaneous utilization of all imagery is recommended as well as stereoscopic viewing for optimal results. The utilization of imagery from different decades is helpful to detect past community disturbances not visible on more recent imagery.

Prairie and coniferous forest communities are best located with the IR imagery, deciduous forest communities with ASCS and SCS imagery. Several quality forests were located along the slopes of the Volga and Turkey River valleys and adjacent uplands in the east-central one-half of the county.

No large prairie tracts were located even though very small disturbed prairie remnants were found. It is believed that larger, high quality prairies would have been located if they indeed are present. No lowland forests or marshlands were identified for preservation recommendation. Different controls or other imagery may be necessary to detect these communities if indeed large quality tracts still remain within the county.

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This Study by: Kendall Duane Wessel

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has been approved as meeting the thesis requirement for the Degree of Master of Arts

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INTRODUCTION

The utilization of aerial imagery to identify potential natural areas is founded on the success of several related field efforts and the ever-present need to reduce the costs of natural area selection. Aerial imagery can provide information ranging from biological to physical features on the Earth's surface. Physical features such as geologic formations and features that illustrate physiographic characteristics are detectable on aerial imagery. Landforms created by deposition of glacial till are characterized by rolling or morainic topography and appear mottled in tonation on panchromatic imagery (Avery 1977). Limestone landscapes commonly exhibit exposed bedrock, sinkholes, and other numerous ground solution features. Surface alignments, eroded surfaces, seepage areas, and drainage patterns of the Ruahine Mountains of New Zealand have been identified using color infrared and panchromatic aerial photography (Stephens 1976). Weathered granite outcrops beneath moderately dense forest canopies were detected on color aerial photographs with a relative scale of 1:4000 (Meyers 1975). MacConnell and Niedzwiedz (1979) successfully applied panchromatic aerial photography to assess stream alteration activities, bank types, and channel characteristics, as well as to identify vegetation and land useage along the White River in Vermont.

Ground-water discharge sites can be located through utilization of aerial imagery. Wood (1972) detected ground-water seeps and springs with flow rates as low as one gallon per minute along the forested banks of the Lehigh River in Pennsylvania. This was accomplished by combining information from low altitude infrared scanning imagery, color photographs, and color infrared photographs. Saline seeps were mapped from aerial color infrared photography which detected the presence of salt tolerant vegetation, wet soil, and exposed salt crust (Dalsted et al. 1979).

Information on vegetation can be obtained from aerial imagery. Boundaries along woody and herbaceous plant communities can also be delineated. Vegetation patterns may result from ground conditions, thus implicating geological features of the area (Svensson 1972). Birnie and Francica (1981) identified zones of mineralized porphyry copper from aerial multispectral scanner measurements of visible and near-infrared radiation reflected by ground vegetation. The data indicated vegetation radiation atop a mineral deposit to have spectra anomalies not found off the deposit. Ecological variation of plant communities can also illustrate geologic differences. For example, Marsh (1978) found wooded tracts in areas of intense agriculture signified terrain unsuitable for cultivation.

White (1978), of the Illinois Natural Areas Inventory, was able to differentiate vegetation into nine community classes utilizing black-and-white panchromatic aerial images. Such classes included forest, prairie, wetland, and cultural vegetation. These were further differentiated on the basis of topographic position, soil moisture, and vegetation structure. Mesic upland forest, wet floodplain forest, and dry dolomite prairie are representative subclasses. Forest/nonforest boundaries and most natural or man-made disturbances can be detected on 1:120,000 scale color infrared film (Aldrich 1975). Specific classes of forest detail detected by various remote sensing methods were areas of no disturbance, past timber-harvest areas, silvicultural treatment areas, recently cleared timber, and areas of forest regeneration. Miller and Myer (1981), incorporating stereoscopic analysis, detected significant plot disturbances following previous analysis of imagery at scales of 1:15,840 or greater. A series of aerial photographs from different years permit detection of disturbances that could not be detected on more recent photographs (White 1978).

Individual forest tree species can be recognized on larger scale aerial imagery by comparing the species photographic texture, tonal qualities, crown shape, and topographic position (Avery 1977). Gammon and Carter (1979) utilized seasonal high and low altitude color infrared photography to differentiate broad-leaved evergreen species from deciduous species within the deciduous forests of the Great Dismal Swamp of North Carolina.

Prairies can frequently be identified on aerial imagery. Both color and black-and-white aerial photography were successfully used to identify remnant prairie communities in the Missouri Natural Areas Inventory (Reese 1982) and the Illinois Natural Areas Inventory (White 1978). Aerial imagery provided identification of most shrub species and herbaceous species with bunch-growth morphologies in a grassland community studied by Carneggie and Reppert (Van Zee and Bonner 1981). They utilized low altitude aerial photographs taken at three different stages of the growing season.

Marshland plant communities and species were located and identified by Seher and Tueller (1973) through simultaneous use of color and color infrared aerial photographs. Gammon and Carter (1979) identified 243 distinct marshland communities in the Great Dismal Swamp using aerial photography.

The quality of the various imagery studies were dependent on the nature of information sought and the kind of imagery techniques utilized. Seher and Tueller (1973), in their marshland study, determined that simultaneous use of color and color infrared film yielded the most accurate vegetation maps. A color infrared and panchromatic film combination, on the other hand, was considered to be of more use in the mountain-feature mapping study by Stephens (1976). Myers (1975) reports color film to be better than color infrared for the study of forest stratification and ground features.

The objectives of this study are to: (1) utilize available aerial photographs to identify specific landtracts in Clayton County, Iowa which may harbor potential natural areas suitable for preservation, (2) evaluate the available county imagery for natural area inventory purposes, and (3) initiate development of an aerial imagery procedure for the identification of potential natural areas.

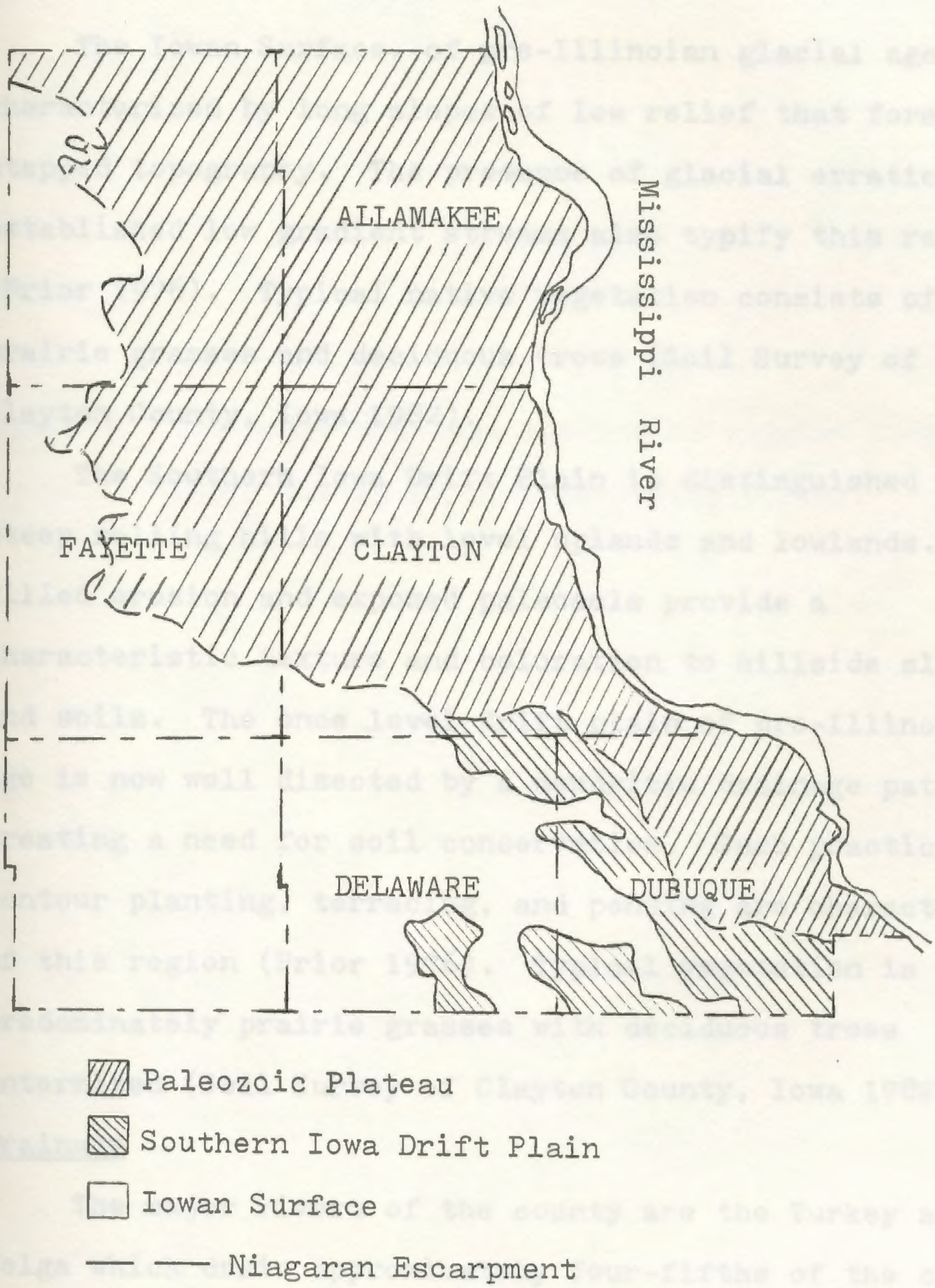
METHODS

Study Areas

Clayton County is located in the northeastern quarter of the state of Iowa and is bordered on the east by the Mississippi River, on the north by Allamakee County, on the south by Dubuque and Delaware counties, and on the west by Fayette County. The county occupies an area of approximately 779 square miles of gently rolling to steep terrain at elevations ranging from 600 to 1,250 feet above sea level (Soil Survey of Clayton County, Iowa 1982).

A major portion of the county is encompassed within the Paleozoic Plateau landform region with smaller projections of the Iowan Surface and Southern Iowa Drift Plain regions crossing the southwest corner and southern border respectively (Fig. 1; Prior 1976). The last glacial period in this region is believed to be pre-Illinoian, providing a longer period of effective erosion to create the current deep, steep-sloped valleys (Hallberg et al. 1984). The plateau topography is controlled by underlying bedrock composed of Silurian, Ordivician, and Cambrian rock formations, unlike the glacial drift plains adjacent to the west and south. Karst features are common in this region as are erosion resistant rock outcrops such as the Niagaran Dolomite escarpment along the western and southern borders. Narrow stream valleys dissect the uniformly level uplands

Figure 1. Landform regions of northeast Iowa (Adapted from Prior 1976).


ALLAMAKEE
Mississippi River
FAYETTE
CLAYTON
DELAWARE
DUBUQUE
Paleozoic Plateau
Southern Iowa Drift Plain
Iowan Surface
Niagaran Escarpment

providing a plateau appearance. The valley slopes are unsuitable for cultivation and may still possess native forest cover (Prior 1976).

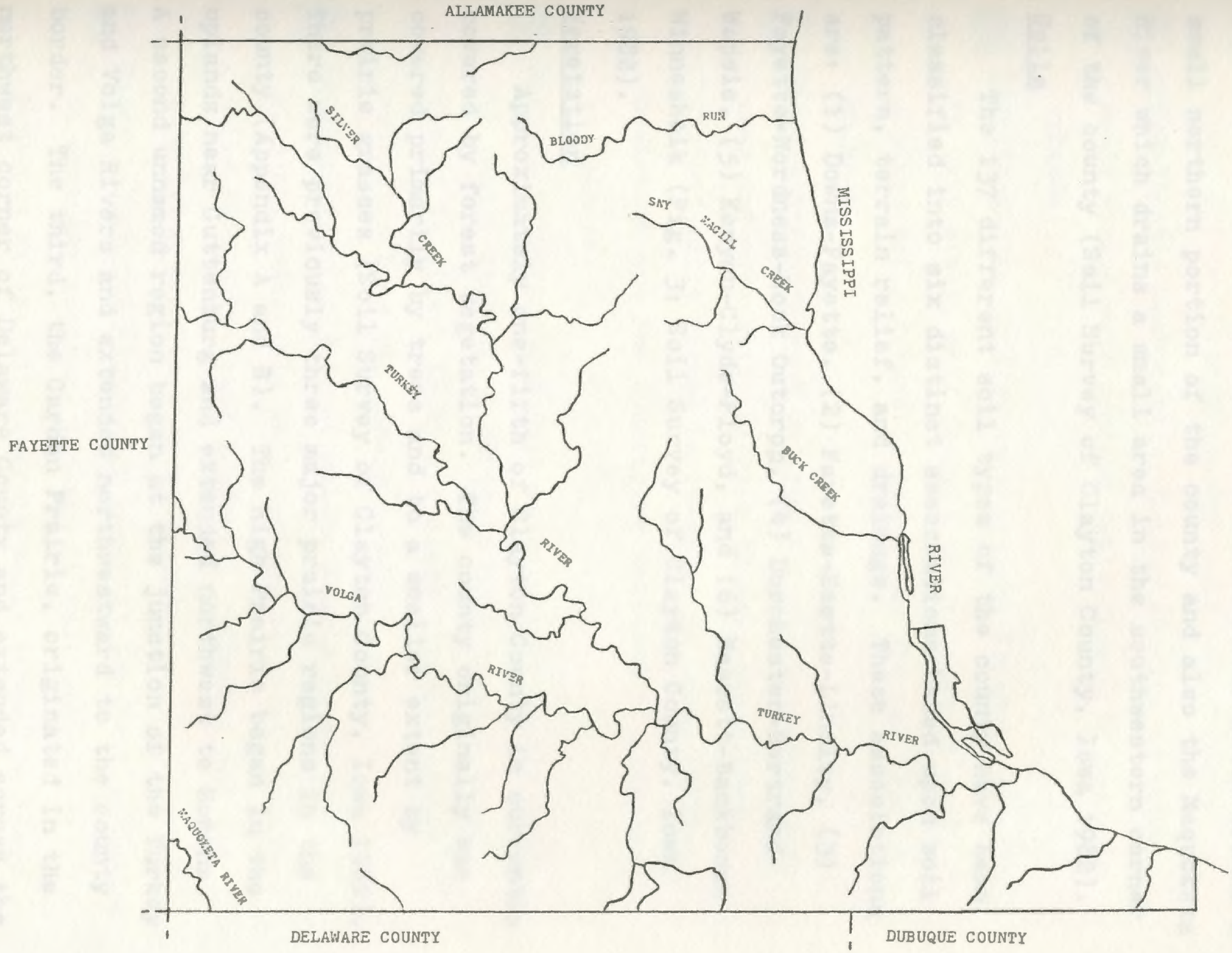
The Iowan Surface, of pre-Illinoian glacial age, is characterized by long slopes of low relief that form a stepped topography. The presence of glacial erratics and established low gradient streams also typify this region (Prior 1976). Typical native vegetation consists of prairie grasses and deciduous trees (Soil Survey of Clayton County, Iowa 1982).

The Southern Iowa Drift Plain is distinguished by steep rolling hills with level uplands and lowlands. Rilled erosion and exposed paleosols provide a characteristic texture and coloration to hillside slopes and soils. The once level drift plain of pre-Illinoian age is now well disected by a dendritic drainage pattern creating a need for soil conservation. Such practices as contour planting, terracing, and ponding are characteristic of this region (Prior 1976). Typical vegetation is predominately prairie grasses with deciduous trees intermixed (Soil Survey of Clayton County, Iowa 1982).

Drainage

The major rivers of the county are the Turkey and Volga which drain approximately four-fifths of the county as they flow southeastward toward the Mississippi (Fig. 2). As the Mississippi River flows southward along the county,

Figure 2. The major drainage systems of Clayton County (Soil Survey of Clayton County, Iowa).


ALLAMAKEE COUNTY
FAYETTE COUNTY
DELAWARE COUNTY
DUBUQUE COUNTY
MISSISSIPPI
RIVER
SILVER
CREEK
BLOODY
RUN
SNY
MAGILL
CREEK
BUCK CREEK
TURKEY
RIVER
VOLGA
RIVER
TURKEY
RIVER
MAQUOKETA RIVER

it also receives water from the Yellow River which drains a small northern portion of the county and also the Maquoketa River which drains a small area in the southwestern corner of the county (Soil Survey of Clayton County, Iowa 1982).

Soils

The 137 different soil types of the county have been classified into six distinct associations based upon soil pattern, terrain relief, and drainage. These associations are: (1) Downs-Fayette, (2) Fayette-Exette-Lindley, (3) Fayette-Nordness-Rock Outcrop, (4) Dorchester-Bertrand-Wapsie, (5) Kenyon-Clyde-Floyd, and (6) Bassett-Backbone-Winnesheik (Fig. 3; Soil Survey of Clayton County, Iowa 1982).

Vegetation

Approximately one-fifth of Clayton County is currently covered by forest vegetation. The county originally was covered primarily by trees and to a smaller extent by prairie grasses (Soil Survey of Clayton County, Iowa 1982). There were previously three major prairie regions in the county (Appendix A and B). The High Prairie began in the uplands near Guttenburg and extended northwest to Monona. A second unnamed region began at the junction of the Turkey and Volga Rivers and extended northwestward to the county border. The third, the Garden Prairie, originated in the northwest corner of Delaware County and extended across the southwest corner of Clayton County into southeast Fayette

Figure 3. The soil associations of Clayton County.

SOIL LEGEND

Downs-Fayette association: Gently sloping to moderately steep, well drained soils formed in loess on uplands.

Fayette-Exette-Lindley association: Strongly sloping to very steep, well drained and moderately well drained soils formed in loess and glacial till on uplands.

Fayette-Nordness-Rock Outcrop association: Rock outcrop and moderately sloping to very steep, well drained soils formed in loess or in loamy surfical sediments and the underlying residuum of limestone; on uplands.

Dorchester-Bertrand-Wapsie association: Nearly level to gently sloping, moderately well drained soils formed in silty, loamy and sandy alluvial sediments on bottom land and stream benches.

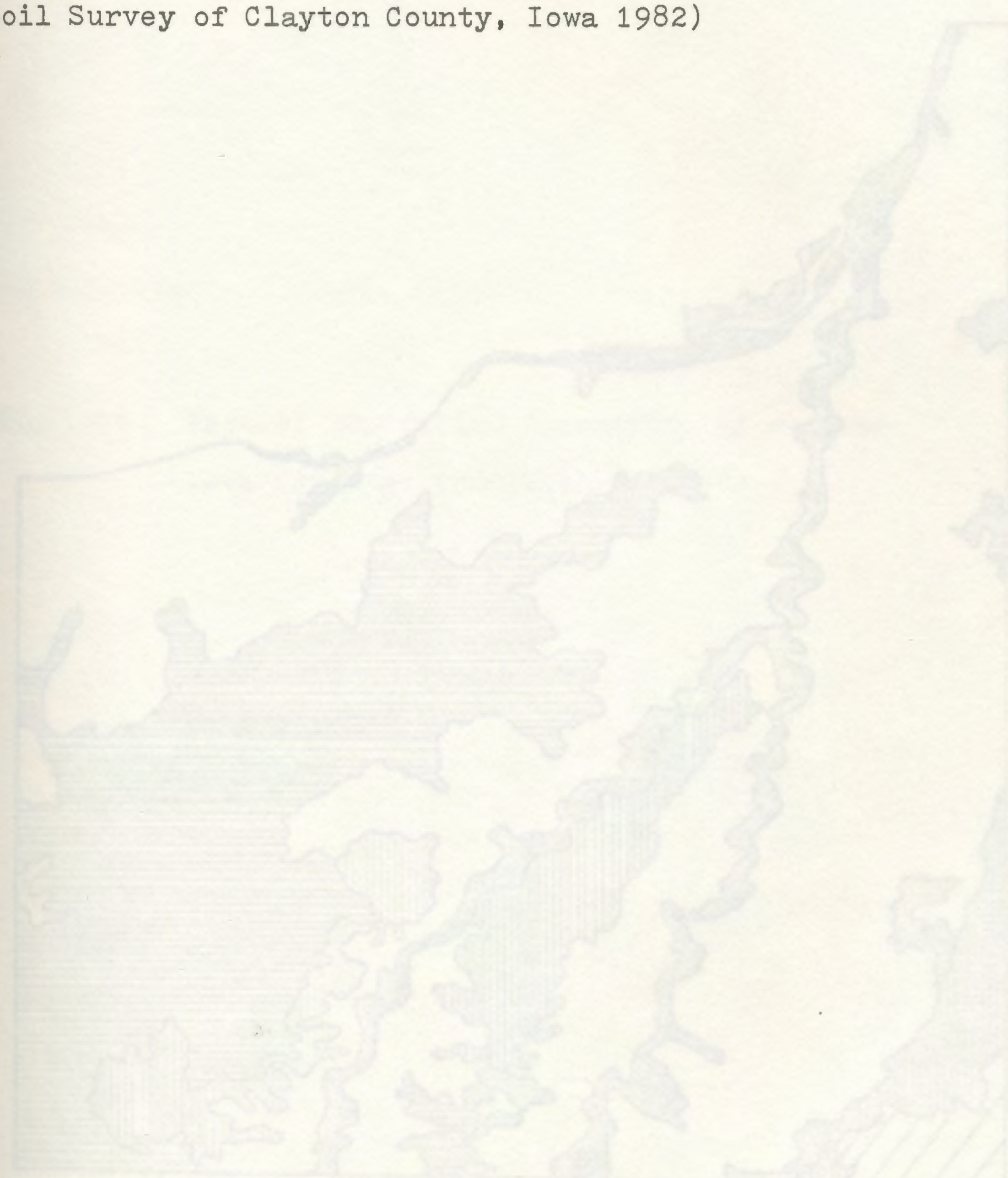
Kenyon-Clyde-Floyd association: Nearly level to gently sloping, moderately well drained to poorly drained soils formed in loamy surficial sediments and the underlying glacial till on uplands.

Bassett-Backbone-Winneshiek association: Gently sloping to strongly sloping, moderately well drained to somewhat excessively drained soils formed in loamy

Figure 3. Continued.

surficial sediments, glacial till and residuum of limestone on uplands.

(Soil Survey of Clayton County, Iowa 1982)



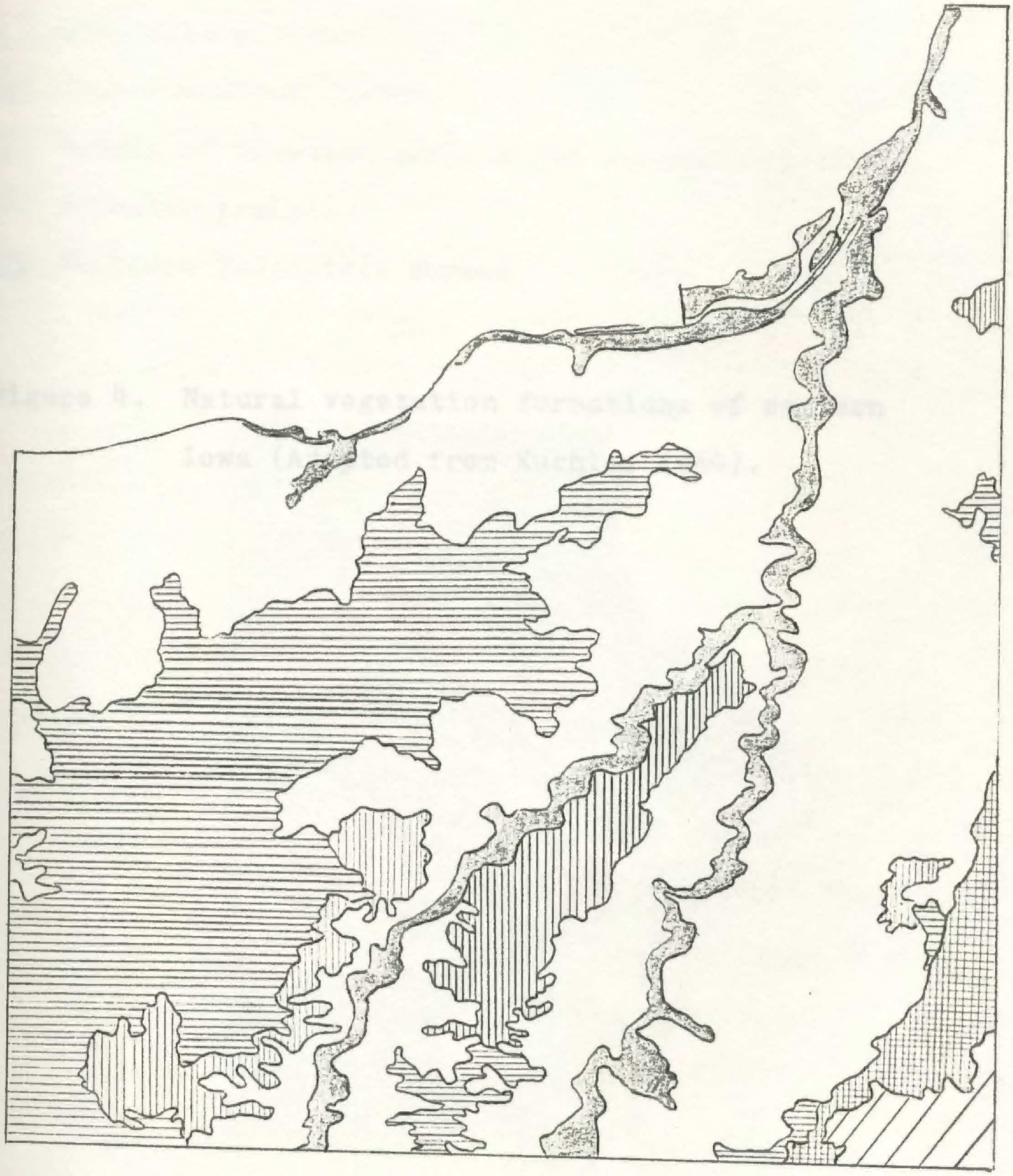
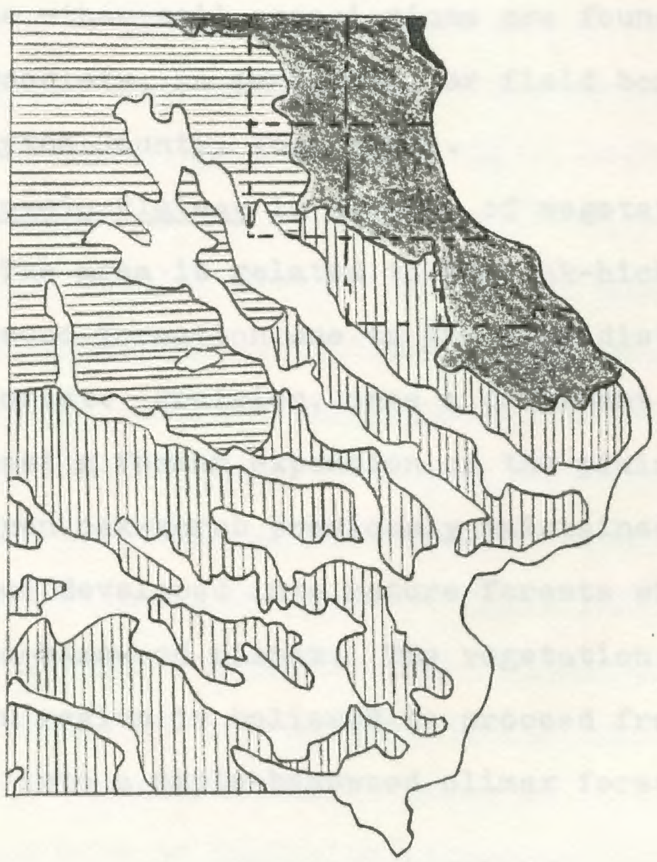


Figure 4. Natural vegetation formations of eastern Iowa (Adapted from Kuchler 1964).

- Oak-hickory forest.
- Maple-basswood forest.
- Mosaic of bluestem prairie and oak-hickory forest.
- Bluestem prairie.
- Northern floodplain forest.



County (Andreas 1875; Trygg 1964). The majority of the upland prairie regions have since been destroyed by cultivation or encroachment of forest.

The largest proportion of forests are found on the Fayette-Nordness-Rock Outcrop soil association. Many of these forests are unsuitable for cultivation due to steep slopes or shallow soil over limestone bedrock. Representative sites of potential natural area value have been located on the upland terrain adjacent to the Mississippi River (Smith et al. 1964). The remaining forests on the other soil associations are found along streams, in woodlots, in fencerows, or field borders (Soil Survey of Clayton County, Iowa 1982).

The Paleozoic Plateau is an area of vegetation transition. The area is related to the oak-hickory southern hardwood formation due to the wide distribution of oak-hickory forest. Prairies, once a prominent vegetation feature, suggest a former expansion of the prairie formation. Open oak-scrub previously maintained by prairie fires has since developed into mature forests with a trend toward a maple-basswood climax. The vegetation succession of the plateau region is believed to proceed from prairie to oak forest into a maple-basswood climax forest (Braun 1950).

The natural vegetation of Clayton County has been classified into formations of maple-basswood forests and a mosaic of bluestem prairie and oak-hickory forests (Fig. 4). The dominant species of each formation are: (1) maple-basswood forest; *Acer saccharum*, *Tilia americana*, (2) oak-hickory forest; *Carya cordiformis*, *C. ovata*, *Quercus alba*, *Q. rubra*, *Q. borealis*, (3) bluestem prairie; *Andropogon gererdii*, *A. scoparius*, *Panicum virgatum*, *Sorghastrum nutans*. Cahayla-Wynne and Glenn-Lewin (1978) reported *Pinus strobus* to be a dominant forest community type, however, it is restricted to relic communities on xeric sites within the two forests.

The county possesses other small communities of special interest based upon diversity and rarity of plant species found within them (Hartley 1962). Maple-basswood forests on steep north and east facing slopes are characterized by species such as *Lycopodium lucidulum*, *Equisetum pratense*, *Taxus canadensis*, *Cypripedium calceolus*, and *Trillium grandiflorum*. Steep north facing limestone talus slopes can provide microclimates for boreal species if cold air drainage is present. Plants characteristic of this community are *Taxus canadensis*, *Betula lutea*, *Linnaea borealis*, *Cornus canadensis*, *Aconitum noveboracense*, and *Chrysosplenium ioense*. Rich upland hardwood forests on dry to mesic soils typically contain species such as *Smilacina racemosa*, *Goodyera pubescens*, *Orchis spectabilis*, and *Liparis lilifolia*. Alluvial forests bordering the rivers and larger streams are subject to periodic flooding and are generally moist or swampy. The typical species found in this community are Acer saccharinum, Populus deltoides, Ulmus americana, Laportea canadensis, Rhus radicans, and several representatives of the genus Carex. Steep west and south facing prairie slopes have a representative cover of Juniperus virginiana, Bouteloua curtipendula, Sporobolus heterolepis, Amorpha canescens, and Petalostemum purpureum.

Procedure

Potential natural communities were selected on the basis of their photographic similarity to known high quality communities. Known or control communities were chosen to provide a representative flora with expected quality defined for all major plant communities in the county. These definitions included ground surveys for species composition and quality. Tonal and texture information derived from aerial photographs of the control communities were compiled with ground survey data to identify photographic "signatures" of these communities. Aerial imagery of the county was then surveyed for communities with similar photographic signatures. These potential sites were ground surveyed for composition and quality to allow comparison with the control sites. The available photographic imagery and search method were then evaluated for future natural area survey use.

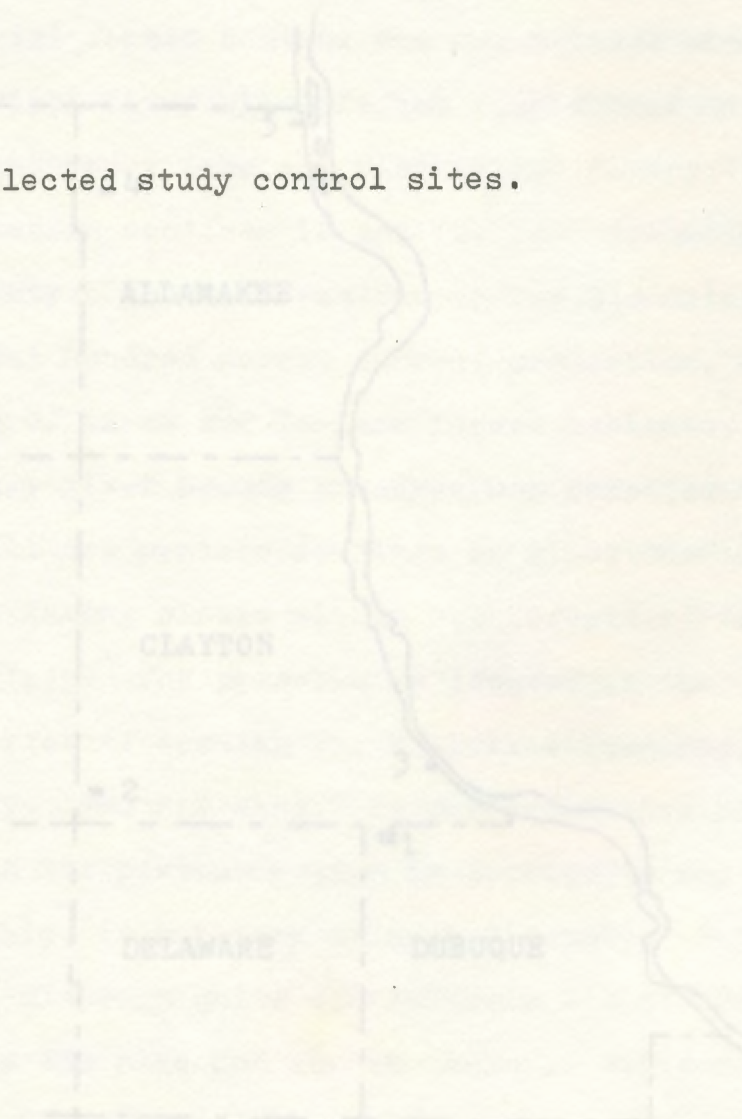
Control site selection and survey criteria

Control communities or sites to serve as baselines were selected from known natural areas utilizing the following criteria: (1) the area must contain one or more of the maple-basswood, oak-hickory, or bluestem prairie plant communities, (2) the area must contain a habitat illustrative of one of the landform regions in the county, (3) a diversity of species representative of a plant community in one of the landform regions must be present, (4) varied terrain exposures should be evident, i.e., examples of upland, lowland, or cardinal directions of slope exposure, (5) the area must be currently preserved, or be deemed worthy of preservation after comparison with preserved areas.

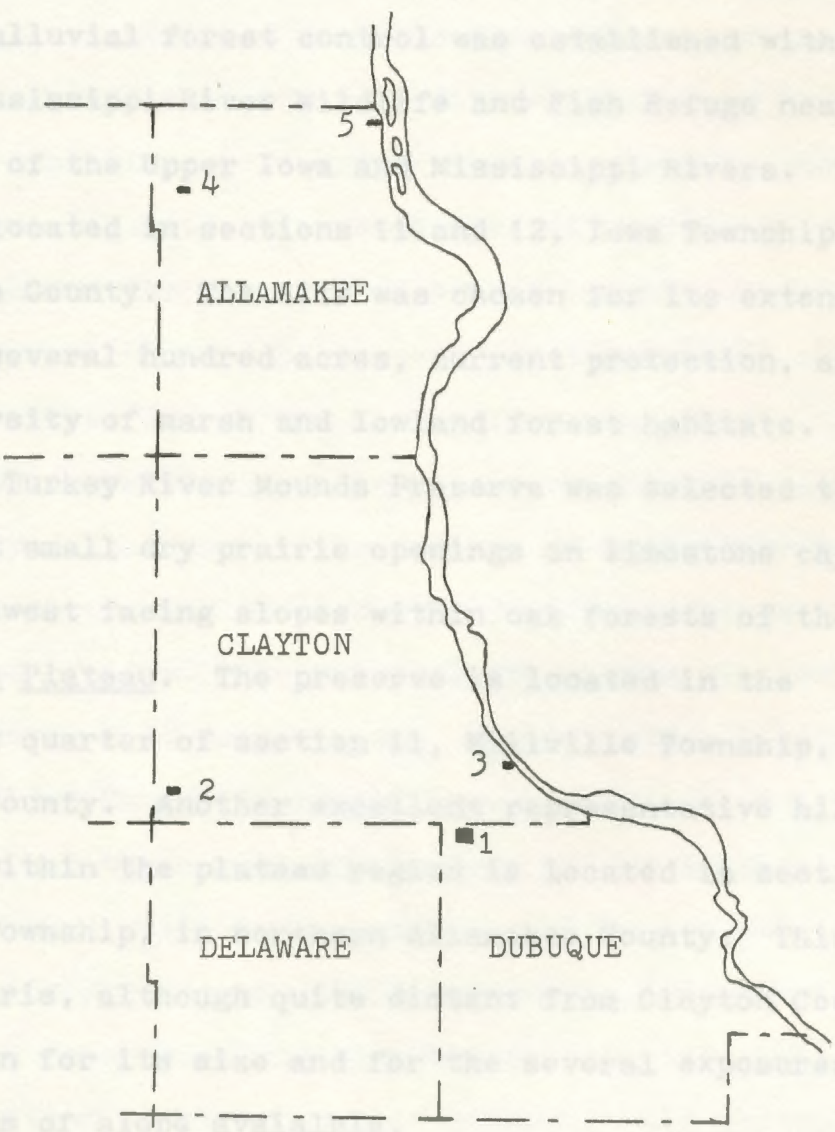
Several quality natural areas exist within or adjacent to Clayton County that meet most if not all of the qualifying criteria. They are White Pine Hollow State Preserve, Bixby State Preserve, Merritt Forest State Preserve, and Turkey River Mounds State Preserve (Fig. 5).

White Pine Hollow, located in sections 5,6,7,8 of Liberty Township, Dubuque County, was judged to be quite representative of the forested habitats in the Paleozoic Plateau. It was selected over other potential sites due to its large size of 660 acres, its documented diverse vascular plant flora of 519 species of 280 genera and 84 families (Thorne 1964), and all cardinal directions of

Figure 5. Selected study control sites.



1. White Pine Hollow
2. Roadside prairie
3. Turkey River Mounds
4. Hillside prairie
5. Marsh and alluvial woodland



slope exposure are evident providing numerable habitats. The most significant habitats present are rolling upland forests dominated by oaks, ridges and bluff crests supporting open white pine-oak forests, north facing talus slopes supporting species commonly found in boreal climates, and north and east facing rocky slope forests in ravines and gorges dominated by maple-basswood (Thorne 1964).

An alluvial forest control was established within the Upper Mississippi River Wildlife and Fish Refuge near the junction of the Upper Iowa and Mississippi Rivers. This area is located in sections 11 and 12, Iowa Township, Allamakee County. The site was chosen for its extensive size of several hundred acres, current protection, and for its diversity of marsh and lowland forest habitats.

The Turkey River Mounds Preserve was selected to represent small dry prairie openings on limestone caprock and southwest facing slopes within oak forests of the <u>Paleozoic</u> <u>Plateau</u>. The preserve is located in the northeast quarter of section 11, Millville Township, Clayton County. Another excellent representative hillside prairie within the plateau region is located in section 9, Hanover Township, in northern Allamakee County. This 27 acre prairie, although quite distant from Clayton County, was chosen for its size and for the several exposures and gradations of slope avaialble.

A 1 acre roadside prairie west of Strawberry Point was selected for its position on the Iowa Drift Plain. The site represents prairie development on black loam soil, and is located in the southeast quarter of the southwest quarter of section 16, Cass Township, Clayton County.

All control sites were ground surveyed utilizing species density plot sampling to establish species diversity, community structure, and habitat quality. The forest communities of White Pine Hollow and the alluvial forest controls were divided into four stratigraphic layers: canopy, subcanopy, shrub, and herbaceous layers. All canopy species within the plot were measured for diameter at breast height (dbh). The subcanopy, shrub, and herbaceous species present within the plot were recorded as was site information on the topographic position, gradient, and evidence of past community disturbance. The forests of White Pine Hollow State Preserve were sampled with 3 circular plots with diameters of 15 m. The alluvial forest was sampled with two 20 meter x 20 meter plots. The prairie habitats of the Turkey River Mounds State Preserve and Allamakee hillside prairies and the marshland habitats of the alluvial forest were surveyed utilizing three 0.1 m plots per habitat. The species present and their percentage contribution per plot were recorded along with topographic information and a listing of other species present. All control site surveys were conducted in the month of September in 1982 and 1983.

Compilation of control photographic signature

Photographic signatures of all control sites were compiled from several different aerial imagery formats. The types of imagery utilized were high altitude color infrared transparencies, low altitude normal color transparencies, and black-and-white panchromatic contact prints.

The Iowa Geological Survey was the source of high altitude color infrared transparencies flown in 1980 at a scale of 1:80,000. The 9 inch x 9 inch transparencies are aligned in sequence of exposure on roll film that requires a special viewing stand for interpretation work. Frames of interest were copied with a 35 mm camera using a copy stand and 64 ASA Ektachrome slide film to eliminate the need for the special viewing stand and expensive duplicates.

Low altitude imagery was obtained from the Clayton County Agriculture Stabilization and Conservation Service. The majority of this imagery is black-and-white panchromatic film obtained from late spring to early fall flights during the past seven years. The original photographs were secured in stereo pairs at a scale of 1:20,000. Enlarged contact prints with four land sections per print are available from the state office. The prints of the more recent flights were enlargements with a scale of 1:7,920. Beginning in 1979 the ASCS has flown aerial coverage of each Iowa county on a 35 mm color slide format. This imagery was flown in stereo, with one land section per slide on imagery from 1979, two land sections per slide on imagery from 1980 to the present. Only the 1979 imagery was available for use at the time of this study.

The Clayton County Soil Conservation Service also possessed low altitude black-and-white panchromatic imagery. The majority of the photographs were out-of-date ASCS contact prints with flightline dates of 1964 and 1956. This office also had black-and-white photography of a similar altitude from 1936. A detailed listing of available imagery can be found in the Guide to Aerial Imagery of Iowa (Anderson et al. 1974).

The 35 mm color ASCS slides and copied slides of the color infrared imagery were viewed on a florescent light table. Low magnification viewing of the imagery was accomplished with a 10x hand lens and a binocular microscope was utilized for higher magnification. All stereo-pair imagery was viewed with a 2x lens stereoscope. All 35 mm prints of the ASCS contact prints were viewed under florescent light with a 10x hand lens and a 2x stereoscope where applicable.

The photographic tones and textures of each control site were related to their respective ground survey data to provide an aerial signature description for each site.

The following interpretative methods were helpful in defining and comparing site descriptions. Stereoscopic viewing allowed the perception of depth which helped delineate differences in forest canopy height and topographic relief. Determination of slope is important since vegetation is influenced by the drier, warmer south facing slopes (Marsh 1978). Slopes that face the sun as well as the vegetation on them will photograph in lighter tones than those that do not since they reflect more sunlight into the aerial camera (Aerial-Photo Interpretation 1966). Smooth roads and dry, bare soil will photograph in white tones due to their high reflectance as will smooth bodies of water if the camera angle is in the correct position (Aerial-Photo Interpretation 1966). Clear water as well as bare, moist ground will appear dark blue-black on color infrared photographs due to the high infrared absorbtion characteristic of water (Sabins 1978). Bare, damp soil will appear dark on normal color and black-and-white photographs as will water if the camera is not in line with the reflected light (Aerial-Photo Interpretation 1966). Abandoned fields, owing to their more diverse vegetation, usually lack the uniform fine texture of cropped fields (Marsh 1978). Pastures are indicated by stock ponds or livestock trails that may appear as faint white lines radiating from barns, pens, or ponds (Avery 1977; White 1978). Planted vegetation will often show a smoother texture than natural vegetation and is usually aligned in a sequential pattern (Marsh 1978). Forests and wetland boundaries are commonly undefined while the boundaries of highways, fields, and railroads are concise (Aerial-Photo Interpretation 1966).

<u>County image search</u>

Imagery encompassing the total landsurface of Clayton County was viewed to select potential natural areas. A major emphasis was placed on the land adjoining the Mississippi River and on the central region west of Garnavillo and Guttenberg through which the Turkey and Volga Rivers flow to dissect the terrain. The above described imagery was utilized to survey the county as was a low altitude black-and-white photo mosaic of the county secured from the government documents section of the University of Northern Iowa Library. This large contact print, secured from a 1970 flight, had value in that it provided an overall view of the county with uniform quality.

The county-wide imagery was initially screened for communities exhibiting tonations and textures similar to the controls. Similar areas were screened further for natural area potential.

Physical features of natural areas, secured from earlier field efforts, were valuable in later imagery screenings. An undisturbed old growth deciduous forest has a relatively continuous even canopy composed of large-crowned trees that create a mottled texture. Protected remnant forests often have straight boundaries, square corners, and lack the row pattern associated with planted forests. Forests that have undergone grazing or selective logging disturbances display canopies that are uneven, have distinct small gaps, or are open through which the ground may be visible (White 1978; Marsh 1978). Heavy logging creates a "ragged" canopy appearance if recent or a "pebbly" texture after several years of recovery (White 1978).

Undisturbed natural prairies and wetlands often persist in irregularly shaped patches due to their existence on soils or topography that cannot be grazed or cultivated (White 1978). The more isolated prairie remnants are found on bluffs, cliff edges, hill tops, eroding limestone outcrops, limestone landscapes showing evidence of underground solution, and sandstone outcrops (Transeau 1935). Wetlands are found within floodplains of streams and rivers, kettleholes, and other low lying areas. Potential prairies and wetlands that have straight borders usually signify the presence of fences. This usually implies the area was previously grazed at one time (White 1978). Since species composition of an area can only be determined by a detailed ground survey, only the most heavily disturbed prairies and wetlands evident on aerial photographs can be eliminated as potential sites (White 1978).

Evaluation of sites as potential natural areas

Forest sites were selected utilizing the criteria listed in Table 1, while Table 2 presents the criteria used to select prairie sites for their value as potential natural areas. All sites were ground surveyed for quality in September and early October of 1983. Two plots per forest community, 20 m x 20 m in area, were utilized to sample each forest site. Each forest stand was divided into canopy, subcanopy, shrub, and herbaceous layers. DBH measurements of all canopy and subcanopy species within each plot were recorded. Species constituting the shrub and herbaceous layers were recorded as was site information pertaining to the topographic position, gradation, and evidence of community disturbance.

Potential prairie and wetland sites were ground surveyed utilizing three 0.1 m^2 plots per community per site. The species present and their percentage of ground coverage within each plot were recorded as were the topographic position, evidence of community disturbance, and a listing of other species present in the adjacent area.

Grading sites for potential natural area value

The grading system developed by White (1978) was selected to evaluate potential natural areas. This letter

Table 1. Criteria utilized to select forest communities.

Site features

A. Must be larger than 20 acres in size.

B. Must have limited cultural disturbance such as roads or buildings.

Canopy features

C. A uniform "velvety" texture composed of large crowned trees is evident (Fig. 6).

D. Few if any trees overtop others enough to cast shadows (exception: forests growing on steep or rocky terrain).

E. Few openings present; if present, they could be rarely more than one crown width in diameter.

F. Few dead or dying trees present.

G. Coniferous species appear red on the infrared imagery.

H. A uniform canopy on film dated 20-30 years prior implies high quality potential since evidence of selective cutting can disappear within 25-30 years.

I. Closed canopies with few crowns per unit area suggest old mature forests.

Figure 6. Photographic examples of criteria utilized to select forest communities.

Top photograph (color infrared photograph of White Pine Hollow).

Site features

(1) Clear cut area with logging road entering from below and leading off to left.

(2) Selective cut area.

Canopy features

(3) Red coloration of coniferous species (*Pinus strobus*).

Bottom photograph (normal color photograph of White Pine Hollow).

Site features

(4) Selective cut area.

Canopy features

(5) Velvety canopy texture


1
2
3


5
4

Table 2. Criteria utilized to select prairie communities.

Imagery appearance

A. Hillside prairies appear chalky blue-grey on the infrared imagery, light green on ASCS color slides.

B. Roadside prairies of the Iowa Drift Plain generally are slightly darker in tone than adjoining exotic road ditch vegetation.

C. Prairies will have a roughened texture and mottled tonation on low altitude ASCS color slides due to the higher diversity of species and habitats present compared to agricultural fields.

Site features

D. The site should show little human perturbation through decades of photography, i.e.; cattle sheds, stock ponds, roads, and fences.

E. Site vegetation must agree with early settlement vegetation and county soil maps to confirm the area is of prairie origin and not of cleared forest.

F. The site has limited access or is located on rocky, steep hillsides or bluffs.

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grading system is based on species composition, the stage of succession of the area, and the degree of disturbance. The grading scale ranges from grade A which represents a relatively stable, undisturbed climax community to grade E which is a community that has had its original vegetation removed, the land surface often has been disturbed, and is going through the first stages of secondary succession. Natural disturbances are graded similarily and range between Bn to Dn grades.

Imagery evaluation

An evaluation of aerial imagery for natural area search utilization has been formulated based on the criteria listed in Table 3.

Table 3. Imagery evaluation criteria.

A. Imagery quality should be consistent throughout.

B. Imagery should be readily available.

C. Imagery is currently in or can be converted into a format that will not diminish interpretation.

D. Imagery resolving power should be small enough to allow detection of the community being sought.

E. Each type of imagery utilized should provide information unique unto itself to prevent imagery redundancy.

RESULTS

Selected Natural Areas

Sixteen potential natural areas were selected from the county-wide aerial imagery search (Fig. 7), of which one-half were ground surveyed for natural quality (Fig. 8).

Upland forest community comparison

A comparison of forest canopies and the subcanopy, shrub, and herbaceous layers of upland forest communities on north facing slopes are presented in Tables 4 and 5 respectively. The ASCS imagery of the White Pine Hollow north slope control displayed a closed canopy with varying crown tonation from multiple species. The canopy was composed of medium to large crowns and had a moderately rough texture due to abrupt changes in slope terrain. The infrared signature was not practical due to the north facing slope shadow from the low angle of illumination. The control community appeared to be in a relatively stable, undisturbed condition, thus it was given the grade of A.

The aerial signature of the Hewett Creek north slope was that of a steeply sloping forest community with a canopy of medium to large crowns of varied tonation. The texture was rough along the slope depicting the steep terrain. A sinkhole on an adjoining upland meadow suggested potential cold air drainage within the community. Even though earlier imagery provided evidence of past intensive

Figure 7. Potential natural areas selected from aerial imagery.

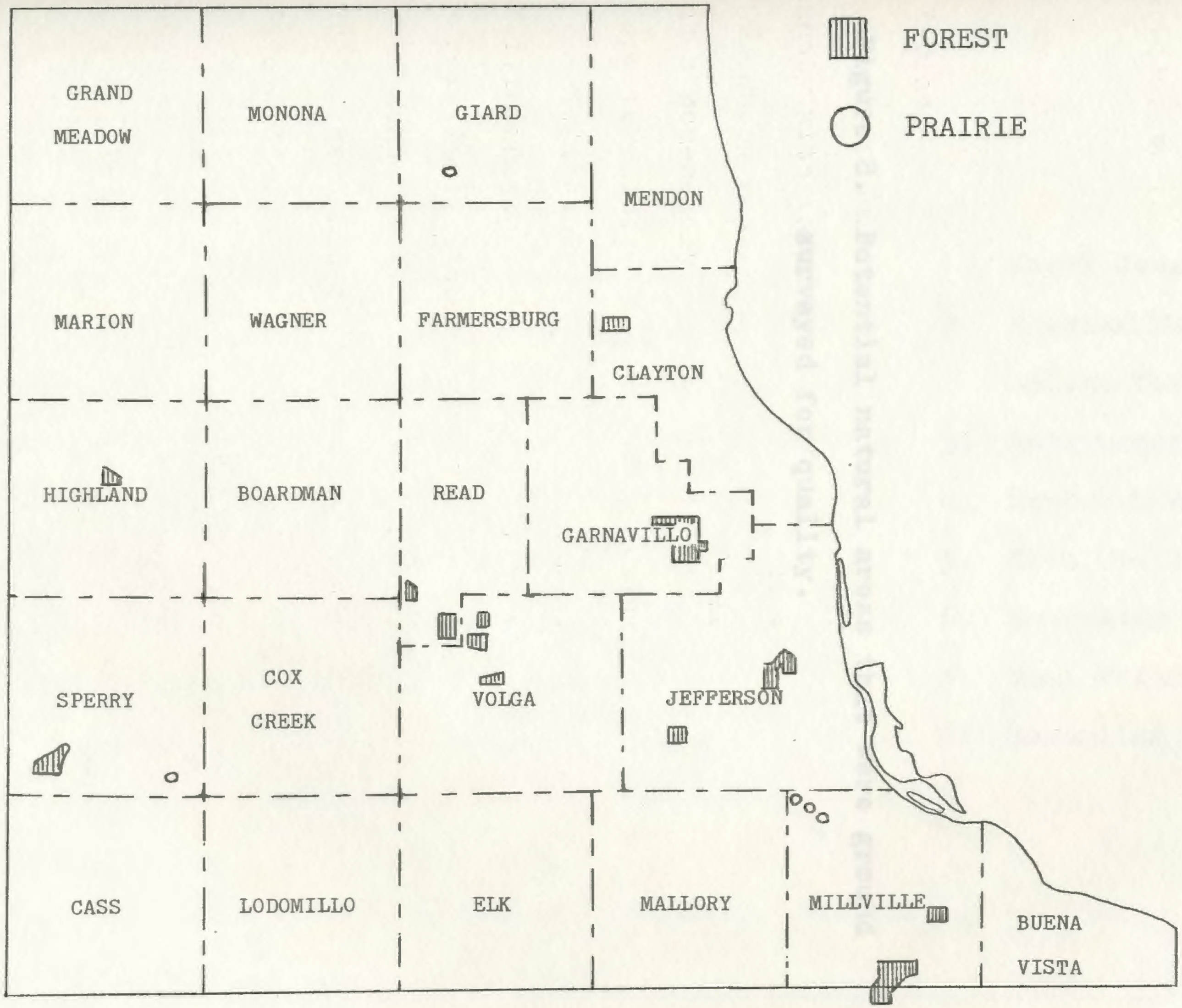
FOREST
PRAIRIE
GRAND
MEADOW
MONONA
GIARD
MENDON
MARION
WAGNER
FARMERSBURG
CLAYTON
HIGHLAND
BOARDMAN
READ
GARNAVILLO
SPERRY
COX
CREEK
VOLGA
JEFFERSON
CASS
LODOMILLO
ELK
MALLORY
MILLVILLE
BUENA
VISTA

Figure 8. Potential natural areas that were ground surveyed for quality.

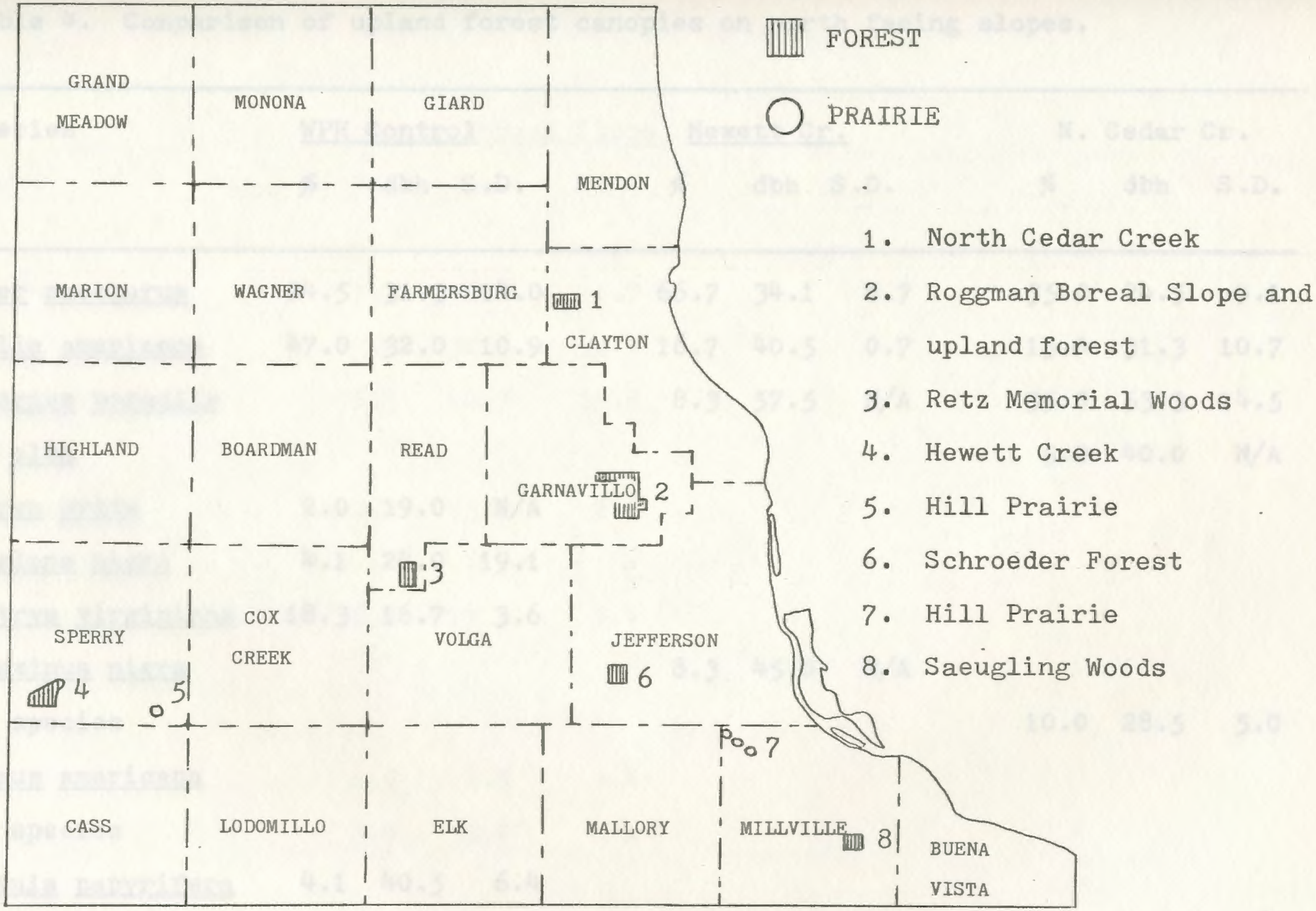
FOREST
PRAIRIE
GRAND MEADOW
MONONA
GIARD
MENDON
MARION
WAGNER
FARMERSBURG
CLAYTON
HIGHLAND
BOARDMAN
READ
GARNAVILLO
SPERRY
COX CREEK
VOLGA
JEFFERSON
CASS
LODOMILLO
ELK
MALLORY
MILLVILLE
BUENA VISTA
1. North Cedar Creek
2. Roggman Boreal Slope and upland forest
3. Retz Memorial Woods
4. Hewett Creek
5. Hill Prairie
6. Schroeder Forest
7. Hill Prairie
8. Saeugling Woods

Table 4. Comparison of upland forest canopies on north facing slopes.

Species	WPH Control			Hewett Cr.			N. Cedar Cr.		
	%	dbh	S.D.	%	dbh	S.D.	%	dbh	S.D.
Acer saccharum	24.5	31.3	14.0	66.7	34.1	8.7	35.0	24.5	9.1
Tilia americana	47.0	32.0	10.9	16.7	40.5	0.7	15.0	31.3	10.7
Quercus borealis				8.3	57.5	N/A	35.0	53.3	14.5
Q. alba							5.0	40.0	N/A
Carya ovata	2.0	19.0	N/A						
Juglans nigra	4.1	24.0	19.1						
Ostrya virginiana	18.3	16.7	3.6						
Fraxinus nigra				8.3	45.0	N/A			
F. species							10.0	28.5	5.0
Ulmus americana									
U. species									
Betula papyrifera	4.1	40.5	6.4						

% = relative density; dbh = mean dbh in centimeters; S.D. = Standard deviation

Table 4. Continued

Species	Roggman Boreal Slope		
	%	dbh	S.D.
Acer saccharum	17.2	34.6	11.7
Tilia americana	45.0	32.5	12.7
Quercus borealis	10.3	44.7	26.8
Q. alba			
Carya ovata	10.3	15.0	2.6
Juglans nigra			
Ostrya virginiana	6.9	17.8	7.4
Fraxinus nigra			
F. species			
Ulmus americana	6.9	18.8	0.4
U. species	3.4	33.0	N/A
Betula papyrifera			

N/A = Not applicable; insufficient quantity to perform calculation

Table 5. Comparison of subcanopy, shrub, and herbaceous layer species presence in upland forest communities on north-facing slopes.

STRATUM Species	White Pine Hollow Control	Hewett Creek	North Cedar Creek	Roggman Boreal Slope
SUBCANOPY:				
Acer saccharum	x	x	x	x
Tilia americana	x	x		x
Ostrya virginiana	x	x	x	x
Ulmus americana		x	x	x
U. rubra				x
Carya ovata				x
Quercus alba			x	
Fraxinus nigra		x		

Table 5. Continued.

STRATUM Species	White Pine Hollow Control	Hewett Creek	North Cedar Creek	Roggman Boreal Slope
SHRUB:				
Acer saccharum	x			x
Betula papyrifera	x			
Ostrya virginiana	x		x	
Taxus canadensis	x	x		x
Tilia americana		x		
Cornus racemosa		x		
Ulmus americana			x	x
Xanthoxylum americanum			x	
Quercus velutina				x
Carya ovata				x

Table 5. Continued.

STRATUM Species	White Pine Hollow Control	Hewett Creek	North Cedar Creek	Roggman Boreal Slope
HERBACEOUS:				
Asarum canadense	x	x	x	x
Adiantum pedatum	x	x	x	x
Hepatica acutiloba	x	x	x	x
Caulophyllum thalictroides	x			
Chrysosplenium ioense	x			
Smiliacina racemosa	x			x
Arisaema triphyllum		x		
Cyripedium calceolus		x		
Actaea pachypoda			x	
Panax quinquefolius			x	
Laportea canadensis			x	

Table 5. Continued.

STRATUM Species	White Pine Hollow Control	Hewett Creek	North Cedar Creek	Roggman Boreal Slope
HERBACEOUS:				
Bidens bipinnata			x	
Amphicarpa bracteata			x	
Sanicula species		x	x	
Acer seedlings			x	x
Ulmus seedlings			x	
Quercus seedlings				x

logging on the adjoining upland forest, the quality potential of the slope was considered to be high. Cold air drainage was found in one area of the community. Overall, the community appeared to be in a relatively stable and undisturbed condition, consequently it was given the grade of A.

The North Cedar Creek north slope aerial signature was that of a moderately steep slope covered with a closed canopy composed of trees with varying height and crown diameters. The extensive adjoining forest displayed a rough texture with small to medium-size crowns suggestive of past logging. This was verified through comparison with imagery of an earlier date. The site was considered to be of intermediate quality based upon the texture and appearance of the canopy at the site and adjoining forest, past logging activity, and the less-steep slope of the site. The shrub layer was variable, being present in one plot, absent in another. The site appeared to have been disturbed in its past but has since regained community stability. This fact along with the sporadic presence of the shrub layer, dense composition when present, and age disparity between the canopy species, warrants the site to be given a B grade.

The canopy signature of Roggman Boreal Slope displayed a closed canopy composed of medium-large crowns of varying tonation on an angle of slope similar to the control.

No signs of disturbance were apparent within the last decade from imagery available. The site was initially considered to have a high quality potential. The final grade was A quality, because it was found to contain similar ground cover as the control and because it appeared to be a relatively stable, undisturbed community.

The canopy, subcanopy, shrub, and herbaceous layers of upland forest communities on slopes with south exposures are compared in Tables 6 and 7. The White Pine Hollow control displayed a complete canopy of varying tonation that was uniform in height across the slope gradient, and had a velvety texture. No evidence of community disturbance was detectable on the imagery nor from the ground survey. The site appeared to be a stable forest community and was graded as having A quality.

The aerial signature of the south facing forest community in Retz Memorial Woods dispalyed a closed canopy composed of medium-sized crowns with a velvety texture and variable tonation. Evidence of disturbance was absent within the site. The initial quality of this site was judged to be equivalent to the control. The final quality grade was grade A since the community was found during the ground survey to be relatively stable with an undisturbed structure.

The Hewett Creek south facing slope displayed a closed canopy of medium to large crowns with a slightly variable

Table 6. Comparison of upland forest canopies on south-facing slopes.

Species	WPH Control			Retz Mem. Woods			Hewett Cr.		
	%	dbh	S.D.	%	dbh	S.D.	%	dbh	S.D.
Acer saccharum	17.1	31.6	7.6	25.9	12.3	1.9	33.3	30.0	9.7
Quercus borealis	78.1	27.7	9.5	18.5	51.1	18.3	37.5	38.4	8.9
Q. alba				22.2	27.8	5.5	20.8	44.6	10.5
Q. ellipsoidalis				3.7	20.0	N/A			
Carya ovata	1.6	12.5	N/A				8.3	27.0	7.1
Fraxinus species	1.6	21.5	N/A	7.4	33.5	14.8			
Juglans nigra				14.8	41.5	4.7			
Ostrya virginiana	1.6	17.0	N/A						
Tilia americana				3.7	30.0	N/A			
Ulmus species				3.7	28.0	N/A			

% = relative density; dbh = mean dbh in centimeters; S.D. = Standard deviation;

N/A = not applicable; insufficient quantity to perform calculation.

Table 7. Comparison of subcanopy, shrub, and herbaceous layer species presence in upland forest communities on south facing slopes.

STRATUM Species	White Pine Hollow Control	Hewett Creek	Retz Memorial Woods
SUBCANOPY:			
Acer saccharum	x	x	x
Ostrya virginiana	x	x	x
SHRUB:			
Cornus racemosa	x		
Xanthoxylum americanum	x		
Acer saccharum	x		x
Ostrya virginiana	x	x	x
Carya ovata			x

Table 7. Continued.

STRATUM	White Pine Hollow Control	Hewett Creek	Retz Mem. Woods
HERBACEOUS:			
Toxicodendron radicans	x		
Parthenocissus quinquefolia	x		
Allium canadense	x		
Desmodium glutinosum	x		
Amphicarpa bracteata		x	
Aster sagittifolius		x	
Adiantum pedatum			x
Hepatica acutiloba			x
Smilacina racemosa			x
Sanguinaria canadensis			x
Panax quinquefolius			x

Table 7. Continued.

STRATUM Species	White Pine Hollow Control	Hewett Creek	Retz Memorial Woods
HERBACEOUS:			
Acer seedlings	x		
Ostrya seedlings	x		x
Carya seedlings			x
Solidago species		x	

color tonation. The texture appeared to be in a state of transition between a rough and velvety quality. Evidence of disturbance of the upland forest was detected on IR and panchromatic black-and-white imagery. The intensity of the disturbance was determined to be minimal although tree stumps from past logging and gully erosion on adjacent land were found during the ground survey. The present community appears to be relatively stable in structure and composition, consequently, it was graded as a B grade community.

Forest communities on level to gently sloping uplands are compared in Tables 8 and 9. The upland forest control aerial signature at White Pine Hollow was that of a closed canopy of uniform height composed of large crowns of varying tonation with an overall velvety texture. The control appeared to be in an undisturbed, stable condition with community structure, thus it was given the grade of A.

The identifying signature of Schroeder forest was that of a forest with protected borders and closed canopy. The canopy appeared to be in a state of transition between a rough and velvety texture and was composed of large crowns of various tonation. Except for a small farm lane leading to the isolated forest, no outward signs of disturbance were apparent. This site was considered to have potential quality falling within the

Table 8. Comparison of forest canopies on level to gently sloping uplands.

Species	WPH Control			Schroeder Forest			Retz Mem. Woods		
	%	dbh	S.D.	%	dbh	S.D.	%	dbh	S.D.
Acer saccharum	28.1	22.4	4.8	4.5	45.0	N/A	33.3	24.2	20.6
Quercus borealis	31.3	58.8	13.6	40.9	66.4	16.6	29.6	32.9	9.6
Q. alba	15.6	40.2	6.6	31.8	52.4	13.0	29.6	39.8	4.5
Fraxinus americana				4.5	24.0	N/A			
F. species	3.1	53.5	N/A				3.7	32.0	N/A
Juglans nigra	18.8	53.7	8.9	4.5	64.5	N/A			
Carya ovata	3.1	16.0	N/A	13.6	48.7	2.3			
Ulmus species							3.7	27.5	N/A

% = relative density; dbh = mean dbh in centimeters; S.D. = Standard deviation

N/A = not applicable; insufficient quantity to perform calculation.

Table 8. Continued.

Species	Site #2			Saeughling Forest			North Cedar Cr.		
	%	dbh	S.D.	%	dbh	S.D.	%	dbh	S.D.
<u>Acer</u> <u>saccharum</u>	29.0	28.4	13.4	13.3	76.5	3.5	41.7	32.0	21.4
<u>Quercus</u> <u>borealis</u>	12.5	47.0	7.9	26.7	81.0	15.9	25.0	48.6	5.0
<u>Q.</u> <u>alba</u>	54.0	38.5	6.3	33.3	42.0	12.1	20.8	39.3	12.8
<u>Tilia</u> <u>americana</u>				13.3	50.8	8.8	12.5	25.7	13.5
<u>Juglans</u> <u>nigra</u>	4.0	45.0	N/A						
<u>Carya</u> <u>ovata</u>	6.7	36.5	N/A						
<u>Ulmus</u> species	6.7	68.5	N/A						

% = relative density; dbh = mean dbh in centimeters; S.D. = Standard Deviation

N/A = not applicable; insufficient quantity to perform calculation.

Table 9. Comparison of subcanopy, shrub, and herbaceous layer species presence in forest communities on level to gently sloping uplands.

STRATUM Species	White Pine Hollow Control	Schroeder Forest	Retz Mem. Woods	Site # 2	Site # 8	N. Cedar Creek
SUBCANOPY:						
Acer saccharum	x	x	x	x		x
Ostrya virginiana		x	x		x	
Quercus borealis		x				
Carya ovata		x				
SHRUB:						
A. saccharum	x	x	x	x		x
C. ovata		x	x	x		
Ulmus americana		x				x
O. virginiana			x	x		
Xanthoylum americanum					x	

Table 9. Continued.

STRATUM Species	White Pine Hollow Control	Schroeder Forest	Retz Mem. Woods	Site # 2	Site # 8	N. Cedar Creek
HERBACEOUS:						
Adiantum pedatum	x	x	x	x		x
Asarum canadense	x					x
Hepatica acutiloba	x					x
Smilacina racemosa	x			x		x
Podophyllum peltatum	x	x	x			
Sanguinaria canadensis	x					x
Goodyera pubescens	x					
Arisaema triphyllum		x			x	
Caulophyllum thalictroides		x				x
Amphicarpa bracteata		x	x			

Table 9. Continued.

STRATUM Species	White Pine Hollow Control	Schroeder Forest	Retz Mem. Woods	Site # 2	Site # 8	N. Cedar Creek
HERBACEOUS:						
Bidens bipinnata			x			x
Maianthemum canadense				x		
Sanicula species			x			
Acer seedlings				x	x	
Ostrya seedlings				x		
Quercus seedlings				x		

A-B range. The farm lane leading to the site was found to extend into the area, effectively bisecting the forest. The forest adjoining this lane exhibited recent disturbance, denoted by openings in the canopy, the presence of a dense shrub layer, and a scattering of tree stumps from past logging activity. It was judged that the impact of logging was minor in the northeast one-half of this area since a well-developed community was apparent. This fact and the similarity of herbaceous composition and community structure to the control, warranted a rating of grade A. The southwest one-half was rated grade B due to the recent community disturbance and structural change.

The aerial imagery of Retz Memorial Woods exhibited a canopy that was closed and had a velvety texture consisting of medium size crowns of varying tonation. No disturbances were detectable on any of the imagery. The potential quality of this site was considered to be comparable with grade A forests. This site was found to be in a relatively stable condition with a community structure similar to the control. Evidence of light grazing was present, but not sufficiently serious to alter community composition. This site was given the A grade of quality.

The canopy of the upland forest at site #2 was interpreted to be closed, uniform in height, composed of medium to large crowns of various tonation and of a velvety texture. No evidence of human disturbance was detected.

The predicted quality of this area was grade A. The area was found to be in a relatively stable and undisturbed condition with a well developed community structure although not of the same composition as the control. This site was given the grade of A quality.

Saeughling Forest appeared to be composed of large crowned trees uniform in height and in canopy texture on early imagery. More recent imagery indicated the canopy to be broken, with some ground disturbance detectable on the IR imagery. Due to the evidence of recent disturbance, the potential quality was not expected to exceed grade B. The original quality and community structure was found to have been destroyed by intensive grazing which had left 70.0% of the herbaceous layer as bare ground. This site was judged to be a heavily disturbed community with a significant change in species composition, consequently, it was given the C grade of quality.

The aerial signature of the North Cedar Creek upland forest was that of a complete canopy composed of small to medium sized crowns. The texture was moderately rough due to variances in the heights of individual trees. No evidence of ground disturbance was detectable through the leafless IR imagery canopy. The potential quality of this site was predicted to be of B grade. Except for a scattering of tree stumps throughout, the site appears to have recovered from past logging and is now in a relatively stable condition. In most of the area, the original structure and composition has not been significantly changed. In some sections however, the shrub layer is altered and the herbaceous layer is basically a carpet of Bidens bipinnata or grass. Overall, this site is of B grade quality with smaller C grade communities intermixed.

Lowland forest community comparison

The imagery appearance of the lowland forest control and adjacent forest was that of a moderatley full to closed canopy of rough texture from variable crown size, spacing, and height. Zones of even-age growth were delineated on all imagery formats and were associated within or near old water channels. Grassy vegetation and/or open water were visible within larger canopy openings or the more recently abandoned channels. Due to periodic flooding, the natural quality of the control was not expected to exceed grade B. The site was found to have been recently disturbed as denoted by a high water mark on the trees, a thick layer of silt on the forest floor, a missing herbaceous layer, and a sparse shrub layer (Table 10). The canopy and subcanopy appeared to have been unaltered by this natural disturbance. The quality grade given to this site was the Bn grade.

No lowland forest communities of similar appearance of potential quality were detected on aerial imagery of the county.

Table 10. Structure of lowland forest control.

STRATUM Species	Relative Density*	Mean dbh in Centimeters	Standard Deviation
CANOPY:			
Acer saccharinum	63.6	38.2	15.6
Betula nigra	9.1	39.3	5.3
Ulmus americana	9.1	17.5	2.1
Populus deltoides	9.1	138.0	63.6
Fraxinus species	9.1	49.5	11.3
SUBCANOPY:			
Acer saccharinum			
SHRUB:			
Ulmus americana			
HERBACEOUS:			
Missing			

* per 0.2 acre.

Hillside prairie community comparison

Hillside prairie survey results are compared in Table 11. The aerial signatures of Turkey River Mounds and Allamakee hill prairie were mainly based on color tonation since texture qualities were difficult to ascertain due to resolution limitations of the imagery. On the color ASCS imagery, the controls appeared in a light shade of green. Adjoining woody vegetation generally was dark green in color although certain individual tree crowns did approximate the prairie tonation. On IR imagery, the control tonations were chalky blue-grey. Precise textural qualities were difficult to ascertain but as a general rule, the controls had a rougher texture than monocultural fields. Both sites had a community structure with a diversity of species. Each site was considered to have grade A quality although both were showing evidence of the need for fire to maintain this quality.

Site 5 is a small rocky outcrop of approximately 250 square feet in area. This site was visible on IR imagery due to the high reflective value of the outcrop which appeared as a white circular area surrounded by dark green woody vegetation. On color ASCS imagery the site was perceived, with difficulty, as a small medium brown to light green area within a disturbed forest community on a south facing exposure. The potential for quality was present based upon the isolation of the area, but a prediction was

Table 11. Comparison of hillside prairies.

Turkey River Mounds Level to 40° slope	Allamakee hill prairie 35° - 65° slope
Dominant vegetation	
Andropogon scoparius	Sorghastrum nutans (lower and mid-slopes)
Bouteloua curtipendula	Andropogon scoparius (upper slope)
Bare ground average	
53.0%	43.0%-lower slope 47.0%-midslope 50.0%-upper slope
Associated species	
Anemone cylindrica	Sporobolus heterolepus
Liatris aspera	Amorpha canescens
Euphorbia corollata	Lespedeza capitata
Amorpha canescens	Castilleja coccinea
Sorghastrum nutans	Spiranthes magnicamporum
Elymus canadensis	Bouteloua curtipendula
Asclepias verticillata	Andropogon gererdii

Table 11. Continued.

Site #5	Site #7
Level rocky outcrop	50^{o} slope
Dominant vegetation	
Andropogon scoparius	Andropogon scoparius
Bouteloua curtipendula	Bouteloua curtipendula
Bare ground average	
90.0%	45.0%
Associated species	
Asclepias verticillata	Amorpha canescens
Anemone clyindrica	Anemone clyindrica
Petalostemum purpureum	Petalostemum purpureum
Juniperus virginiana	Juniperus virginiana
Rhus species	Heuchera species

not feasible due to the lack of aerial information. A ground survey of the site determined that 90.0% of the outcrop was bare rock. Three smaller grassy areas with a low diversity of prairie species were found adjacent to the outcrop and under a canopy of *Populus tremuloides* and *Juniperus virginiana*. The site is currently experiencing two types of disturbance, grazing and the absence of fire. The latter is the most pronounced in intensity. The quality appearance of the area is Dn grade due to the lack of community structure and species diversity. This is the grade assigned to a former prairie covered by trees and brush with only scattered prairie plants remaining (White 1978).

Site #7 is composed of three small grassy outcrops on a southwest facing bluff above the Turkey River. From interpretation of the IR imagery, a broad band of *J. virginiana* was observed to traverse the bluff slope. This species is a common early invader of prairies. Due to the timing of exposure and photographic characteristics of this imagery, the *J. virginiana* colony was displayed as a red "ribbon" along the slope. This was in sharp contrast with adjacent leafless deciduous trees whose trunks were greenish-brown in color. A check of black-and-white prints from 1956 found the area once as an open grassy slope undergoing woody plant invasion. Interpretation of color ASCS imagery provided three just-perceptible grassy openings within the forest canopy. The color tonation of these openings were light green to medium brown. No texture qualities were obtainable from such small targets, thus a quality prediction was not feasible. The openings were found to be dry dolomite outcroppings covered primarily by Androgon scoparius and Bouteloua curtipendula. Other prairie species present were too low in number to contribute to community structure. The openings were determined to be low quality remnants of a former prairie that has since undergone woody plant invasion, thus the Dn grade was assigned.

Level upland prairie community comparison

Survey results of the level upland prairie control are presented in Table 12. The aerial signature of the level upland prairie (control #2) was similar to the hill prairie tonations and textural qualities. It was also found to be moderately darker in tonation than adjoining hay meadows or grassy roadside vegetation. The site was found to contain a diversity of prairie species that provided a community structure judged to be of A quality. No potential prairie sites of this type were found during the aerial survey.

Marshland community comparison

Survey results of the marshland control are presented in Table 12. The appearance of the site on aerial imagery is that of a grass and forest covered area interlaced with

Table 12. Survey of level upland prairie and marshland controls.

Control #2		Marshland control
Prairie on level loamy soil		
Dominant vegetation		
Andropogon scoparius		*Spartina* sp.
Andropogon gererdii		
Bare ground average		Bare ground/standing water
13.5%		5.0.%
Adjacent species		
Rosa carolina	*Erigeron annuus*	*Saggitaria latifolia*
Liatris aspera		*Typha latifolia*
Echinacea purpurea		*Aster junciformis*
Anemone cylindrica		*Helenium autumnale*
Solidago rigida		*Asclepias incarnata*
Fragaria virginiana		
Lespedeza capitata		

stream channels and ponds. On IR imagery, the marsh vegetation appears as a "dirty" or off-white color. On ASCS color imagery, it appears in various shades of green. On the IR imagery, bands of different vegetation could be delineated around stands of open water. Like prairie imagery, texture qualities were difficult to establish because it was beyond the limits of imagery resolution. The site was found to be in an undisturbed state with community structure and a diversity of species. The quality of the control was judged to be of A quality. No similar sites were found within the county during the aerial survey.

Imagery Evaluation

The majority of the imagery formats utilized in this study were consistent in image quality. Only the ASCS color transparencies displayed tonal variation and quality loss. Photographic haze and, on rare occasions, cloud cover created color and resolution distortion that hindered interpretation of fine details.

Access to the imagery was readily available for in-office viewing if appointments were prearranged. Short term loans were available for 35mm color ASCS transparencies that were three years old and for SCS black-and-white contact prints from 1964. The high altitude IR imagery was also available for loan but only to state affiliated research projects.

The 35 mm color ASCS transparencies were the easiest to process for interpretation. This format was less bulky and required less transportation and protection precautions. The black-and-white ASCS and SCS contact prints and the IR roll transparencies were easily duplicated into the 35 mm format in either print or slide form. No significant color or resolution distortion resulted from this procedure. The special viewing table required for the IR transparencies is not necessary for interpretation of the 35 mm color duplicates and little resolution is lost. Survey efficiency was increased since this format was easily taken into the field for reference.

Most of the communities were resolvable on the imagery utilized. Steep north facing slopes on the IR imagery could not be interpreted as they were hidden by slope shadow. Individual trees and canopy textures were easily resolved on ASCS black-and-white and color imagery. Only individual coniferous trees could be resolved on the IR imagery since their bright-red appearance contrasted sharply with the greenish-brown background of deciduous forests or the white background of dormant grassy vegetation. Since this imagery was exposed after leaf drop, canopy texture could not be determined but partial views of the forest floor were provided and disturbances such as gullies and roads were resolvable. Prairies as small as 1 acre and some texture qualities were resolvable on the ASCS imagery. The 35 mm color ASCS imagery from 1979 allowed resolution of smaller details than similar imagery dated 1980 or later. The 1979 imagery was flown at an altitude that provided one land section per slide. The more recent 35 mm imagery is flown at a higher altitude and provides two land sections per slide which results in a loss of resolution. Prairie textures could not be resolved on IR imagery due to the high altitude exposure, but prairies as small as 1 acre were detectable by the sharp contrasts in vegetation.

Recommended Procedure For Natural Area Searches

A recommended procedure to utilize aerial imagery for natural area searches has been established based on the criteria listed in Table 13. It is important to utilize the most recent imagery and imagery with exposure dates spanning several decades. To illustrate, a potential railroad prairie site had been destroyed since the date of exposure of the most recent imagery available for this study, that being dated four years prior. Had the more current imagery been available, this site would have more than likely been eliminated as a potential site. It is helpful to view imagery spanning 20-30 years, since past disturbances may not be as evident on current imagery. An example is a forested tract of land that upon initial viewing of the most recent imagery had a full, uniform canopy of potential quality. Viewing photographs dated 47 years earlier showed half of this area had practically been clearcut. Reviewing the recent imagery with more scrutiny revealed crown shapes and subtle photographic textures illustrative of a past disturbance.

Table 13. Suggested imagery and procedures to accommodate natural area searches.

A. Utilize the most recent imagery available and imagery with exposure dates spanning several decades.

B. Have all imagery available simultaneously for interpretation work.

C. Interpret imagery stereoscopically where applicable.

D. Consult topographic and soil maps for comparison with imagery interpretation.

E. Utilize the largest imagery scale available to search for natural prairie.

F. Utilize fall season infrared imagery for prairie searches as it delineates prairie grasses best.

G. The best results of the forest survey were obtained utilizing the ASCS color and high altitude infrared transparencies in unison.

The best results for site selection are accomplished utilizing all imagery formats available simultaneously for interpretation. This allows direct comparison between imagery differences of tonation, texture, and resolution which are, at best, difficult to record in writing for later referral. The telltale signs of forest disturbance previously described would have been difficult to formulate without direct imagery comparison.

The majority of the potential natural areas were selected through steroscopic interpretation of the imagery. Topography changes not readily apparent on a single image are easily discerned on imagery exposed in stereo. Changes in canopy height could be accredited to either terrain differences or past logging activity. Tree crown diameters are also more apparent if viewed in stereo. This can provide an age estimate of the site and the approximate elaspe of time since the last significant disturbance. Determination of the angle of slope can aid prairie searches. Slopes that appear too steep for cultivation and grazing have a higher potential for containing prairie remnants than do more gentle slopes. An unused portion of a field may be determined to be too rocky to cultivate, a grass filled sinkhole, or a grassy waterway instead of a potential prairie utilizing this method. In some situations where stereoscopic viewing of stereo pairs is not practical there may be enough texture and tone difference between the stereo images, viewed separately, to either accept or reject a site.

Valuable information on a potential site may be gained through utilization of topographic and soil maps. Cultural features such as roads and fences not visible through a forest canopy may be noted. The location of buried pipe lines, abandoned roads, and mines can provide answers to unexplained disturbances. The angle of slope is provided on topographic maps, aiding prairie searches. Most springs and sinkholes are marked providing location clues for potential north facing cold air talus slopes at sites selected from imagery surveys. Soil maps provide information on the soil types found within a locality and the natural vegetation expected or previously known to be growing on them. This allows testing of a site to check if a potential prairie is on prairie soils instead of soils of a cleared forest before an on-site inspection is made.

The largest imagery scale available should be utilized to search for natural prairie. Due to the morphology of prairie vegetation, the resolution necessary for quality establishment is more acute than that required for forest searches. As the altitude of exposure of the imagery utilized in this study increased, resolution diminished. The smaller prairie control sites, definable on the larger scale ASCS imagery, were barely discernible on the smaller scale IR imagery.

The fall season IR imagery utilized in this study was found to be of value in predicting the location of potential prairie remnants on rocky outcrops or in grassy openings on hillslopes not otherwise discernible. These potential sites were found associated with stands of *Juniperus virginiana*. This species appears as red "ribbons" or "spots" in areas of heavy infestation along bluffs and hillslopes. Prairies larger than 5 acres were identifiable due to the sharp contrasts and specific tonation provided by this imagery.

The best results of the forest survey were obtained utilizing the ASCS color and high altitude IR transparencies in combination. Detailed features such as crown size, canopy texture and uniformity were interpreted utilizing ASCS imagery. Ground disturbances not detectable under closed summer forest canopies were detectable on the IR imagery due to its exposure after leaf drop. The IR imagery also allowed delineation of coniferous and deciduous vegetation.

DISCUSSION

Imagery Utilization

The utilization of aerial imagery can provide valuable assistance to natural area surveys. If adequate film coverage is available, preliminary aerial interpretation can provide the location of areas that should be given priority evaluation. Aerial imagery saved both time and money in an Oregon natural area survey by eliminating visits to sites of lesser potential and allowing the concentration of resources on areas that appeared to have higher potential (Mairs 1976).

Historical changes at a site may also be noted if the appropriate films are available and utilized. Older imagery from an earlier decade may show disturbances that are no longer apparent on recent imagery. White (1978) found this particularly true with hill prairie communities that were once more open but gradually blended with surrounding forests due to woody invasion. Forest disturbances, especially in areas that experience frequent changes, are best detected when compared with earlier dated imagery (Aldrich 1975). Reese (1982) found the comparison of different dated imagery to be an effective procedure to eliminate questionable prairie sites.

Proficiency in interpretation can be acquired in a relatively short time if appropriate "self" training is coupled with ground verification. Several types of cover vegetation can be readily recognized once their characteristic signatures are learned. Dormant vegetation such as prairie grass can appear white on color IR imagery (Sabins 1978). In this study dormant prairie on IR imagery ranged from chalky white to blue-grey because of the angle of illumination and the variation in tonation caused by film processing. The results of this study were similar to those by Reese (1982) who also interpreted upland prairies to have a dark green signature on color ASCS imagery that was unlike adjoining vegetation. As Cowardin and Myers (1974) reported, the individual crowns of coniferous species such as Pinus and Juniperus appeared on late fall IR imagery as pink or red dots providing sharp color contrasts with surrounding vegetation.

There are several disadvantages inherent to aerial imagery. Color ASCS imagery is apparently gaining a reputation for having low contrast, poor resolution and tilt distortion since these characteristics were commented on by Reese (1982). These characeristics were occasional problems in this study, but they did not significantly diminish the value of the imagery. These effects can be reduced if the imagery is stereoscopically viewed with flourescent light, or if the image frame provides a direct overhead view of the site centered in frame and not adjacent to the border. Centered subjects eliminate color tone misinterpretation that can occur at imagery edges (Lovvorn and Kirkpatrick 1982). Species identification on color ASCS imagery is not generally practical since there is insufficient tonal variation in the canopy. Finer tree details such as crown shadows, shapes and branching patterns that can be useful in identification (Avery 1977) were not resolvable. Since herbaceous, shrub and subcanopy species are important community components which do not occur on the imagery, ground validation of potential sites can not be eliminated.

ASCS imagery may become less accessible in the future since ASCS regulations require the disposal of color transparencies within three years of exposure. Black-and-white contact print enlargements are also to be disposed of as they become out-of-date (Reese 1982). The current fate of the imagery is left to the discretion of the county office directors. In the past the imagery has gone to county SCS offices but some has been distributed among other state offices or universities.

Imagery Analysis

It is recommended that the following procedures be incorporated into future natural area surveys utilizing imagery analysis: (1) determine what state and county agencies or other possible sources have appropriate imagery coverage of the area to be surveyed, (2) become familiar with the landforms, vegetation and ecological relationships known to the area, (3) select imagery controls from known prime natural areas or preserves representative of the area that can be ground surveyed for community quality, (4) relate aerial signatures of controls to land quality if possible, (5) utilize soil and topographic maps to provide additional site information to aid imagery interpretation of signatures, (6) view the imagery stereoscopically if possible to facilitate interpretation of terrain and cover vegetation textures, (7) survey aerial imagery for signatures similar to the controls utilizing current and dated imagery simultaneously, (8) ground survey potential sites for natural area quality.

When utilizing IR imagery, select imagery from spring or late fall through late winter since the discrimination between leafless deciduous hardwoods and evergreen conifer trees is optimal (Aldrich 1975).

Natural Area Potential In Clayton County, Iowa

The potential natural areas in Clayton County were located predominately in the east-central one-half of the county near the Volga and Turkey Rivers. These regions also contained some of the greatest terrain relief in the county, perhaps linking their presence with inaccessibility to agricultural utilization.

Several quality forest communities were found on the upland terrain and north and south facing river valley slopes and probably have been protected from agricultural use due to thin, rocky soil or steep gradients (Soil Survey of Clayton County, Iowa 1982). The sites selected by Smith et al. (1977) were either: (1) not chosen because they had originally been selected for scenic value which was not utilized as an evaluation criterion, or (2) were determined to be of lower quality than other potential areas due to disturbances that apparently have occurred since their study.

No sites of potential quality lowland forest or marshland were found, although the alluvial forest controls were easily discerned. The failure may be attributed to poor alluvial controls and difficulty in interpreting the small inland streams or few remain. Roosa (1984) suggests that the habitat is a rapidly disappearing community in the region. Other imagery may be necessary since other authors have had success with color IR at scales similar to ASCS imagery in several wetland study areas (Lovvorn and Kirkpatrick 1982; Gammon and Carter 1979). White (1978) reported late summer-early fall to be the best survey time for wetlands; several months after ASCS imagery is usually exposed.

The prairie controls appear to be the only quality prairies in the county. The fact that no additional quality prairies were found during this study suggests that they likely do not exist. Since very small disturbed prairie remnants were found, it is believed that a large, high quality prairie would have been found if it were present.

CONCLUSION

The utilization of ASCS, SCS, and IR imagery is an efficient method to locate most potential natural areas. Quality predictions of selected sites are restricted to the association level of vegetation classification since subcanopy species information is not provided by this imagery. Ground surveys of selected sites can not be eliminated as subcanopy information is an important part of community quality evaluation.

Simultaneous utilization of this imagery is recommended. The high altitude color IR imagery provides sharp color contrasts between vegetation communities that allows their delineation but the imagery lacks adequate resolution of fine details. The ASCS and SCS imagery lack in color contrasts but provide resolution of details not discernable on the IR imagery. The false vegetation coloration of the IR imagery can be correlated with the normal coloration of the color ASCS imagery to verify vegetation identification.

Prairie and forest communities can be located utilizing this procedure. Prairie and coniferous forests are best located with IR imagery. Deciduous forest communities are evaluated best by the utilization of ASCS and SCS imagery although IR imagery is helpful by providing views of forest floor disturbances. Re-evaluation of the procedure and of the imagery is recommended for wetland studies as there were not any potential sites found to compare with the controls.

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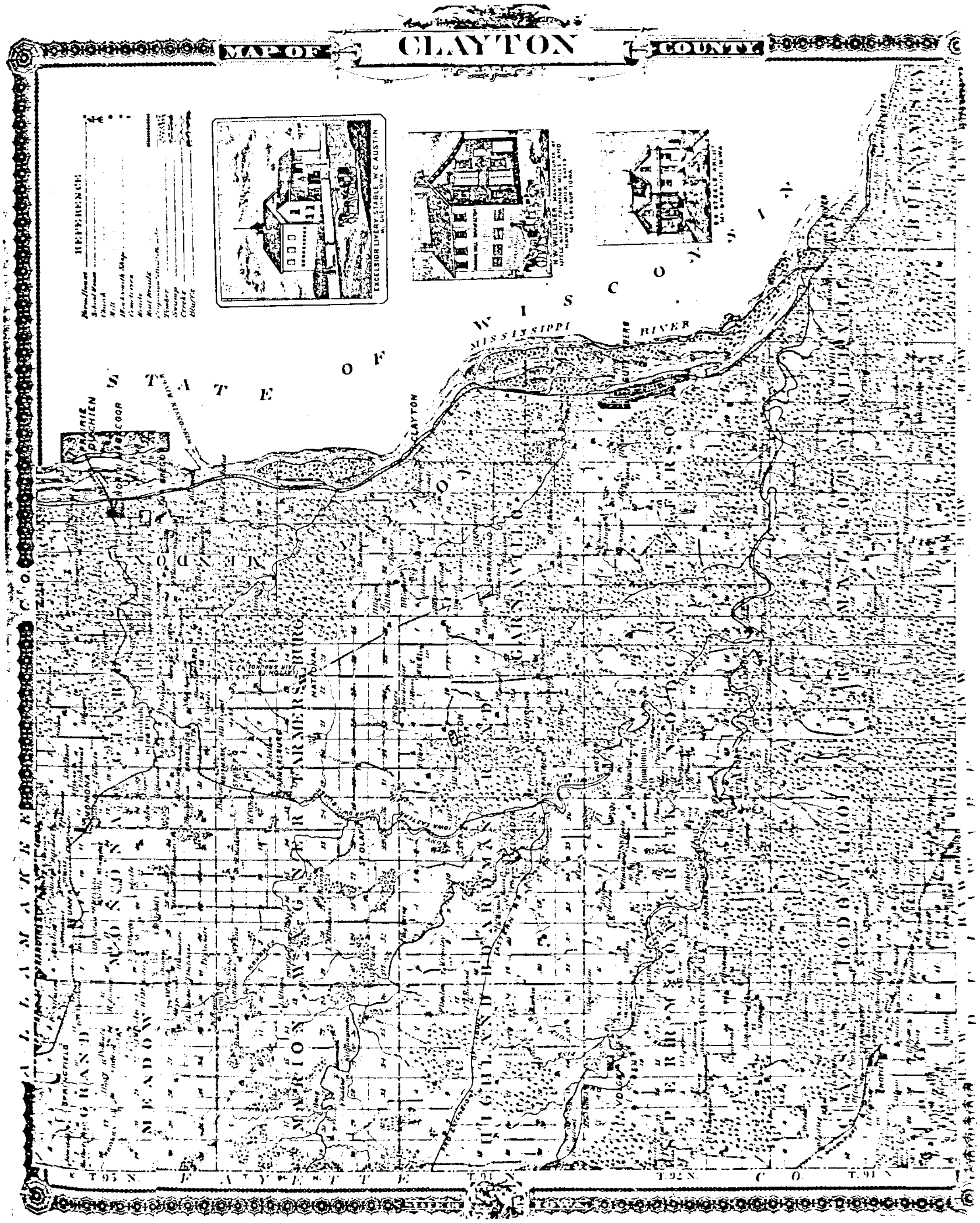
APPENDICES

Appendix A

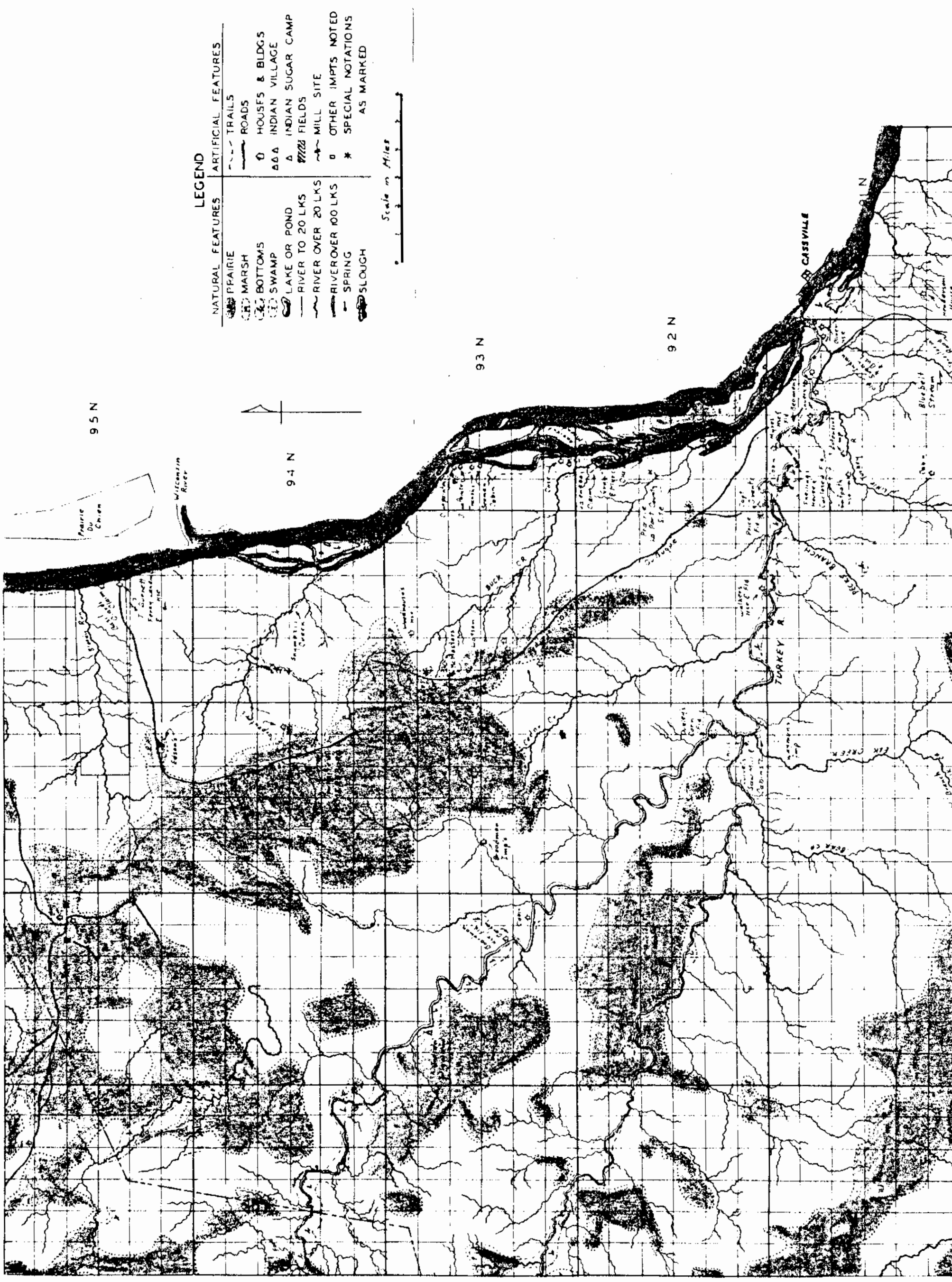
Early settlement and vegetation map of Clayton County (Andreas 1875).


MAP OF
CLAYTON
COUNTY
STATE OF WISCONSIN
MISSISSIPPI RIVER
CLAYTON
EXCELSIOR LIVERY STABLE W. C. AUSTIN
FAYETTE CO.
T. 93 N.
T. 92 N.
T. 91 N.

Appendix B

Pre-settlement vegetation map of Clayton County compiled from surveyor's original plats and field notes (Trygg 1964).

 = Prairie vegetation.


LEGEND
NATURAL FEATURES
PRAIRIE
MARSH
BOTTOMS
SWAMP
LAKE OR POND
RIVER TO 20 LKS
RIVER OVER 20 LKS
RIVER OVER 100 LKS
SPRING
SLOUGH
ARTIFICIAL FEATURES
TRAILS
ROADS
HOUSES & BLDGS
INDIAN VILLAGE
INDIAN SUGAR CAMP
FIELDS
MILL SITE
OTHER IMPTS NOTED
SPECIAL NOTATIONS AS MARKED
Scale in Miles
95 N
94 N
93 N
92 N
91 N
CASSVILLE
Prairie Du Chien
Wisconsin River
TURKEY R
ELK CREEK