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A Municipal Inventory and Evaluation of Natural Areas: History and Methodology

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An inventory of natural areas in the vicinity of Ames, Iowa was conducted (1990–1994) in response to conflicts arising when significant natural areas were encountered on lands approved for development by the City of Ames (Iowa) Planning Office. Methods for objective evaluation of woodland and prairie quality were developed for use during the inventory. The woodland method is based on four components: I) *Diversity* of expected species, II) *Structure* of canopy and understory layers, III) *Fidelity* of species to the habitat and IV) absence of *Introduced Species*. Rules are explicitly stated for the scoring of each component for both the canopy and understory within 0.1 ha circular plots. Diversity receives twice the weight of the other components, and the scores from all four components are summed to yield a Woodland Quality Rating (WQR) between 0 and 20. Survey points are marked on a topographic map prior to survey. These are chosen to represent principal topographic aspects of a woodland and are allocated in proportion to the area of the tract. The prairie method is based on a single component: diversity of prairie plant species. After survey, quality ratings are marked on maps to allow delineation of quality regions into one of four categories: A) Highly Natural, B) Mostly Natural, C) Moderately Altered, and D) Highly Altered. A total of 928 ha (2,294 ac) was surveyed and evaluated using this method. Maps and written descriptions of evaluated areas were compiled in an inventory report submitted to the City of Ames Planning Office.

INDEX DESCRIPTORS: natural areas, Ames, Iowa, evaluation, inventory, conservation, vegetation survey.

An inventory of natural areas in the vicinity of Ames, Iowa was conceived in 1990, largely as a result of complications that arose on the sites of two separate development projects approved by the City of Ames (Iowa) Planning Office. In both instances, prairie remnants were encountered on land targeted for development. Following a large public outcry for their protection, the Ames City Council spent many hours in public forum negotiating easements with the development firms to ensure protection of these areas. In both cases, knowledge of these prairie remnants prior to the issuance of development permits would have saved developers and the City of Ames time, money and adverse publicity. These events provided the impetus for the Ames Natural Areas Inventory (1990–94) which ultimately would consist of the survey and evaluation of significant vegetation communities in Ames.

THE STUDY AREA

Ames (population: 48,691) is located in Story County in central Iowa (Fig. 1). The city occupies an area of approximately 5,957 ha (14,720 ac). Ames sits on a landscape that was covered by a glacial ice sheet 14,000 to 12,000 years ago (the Des Moines Lobe) which receded 12,000 to 11,000 years ago (Prior 1991). The soils are some of the most fertile in the world and consequently almost all of the surrounding land has been converted to cropfields.

A major river, the Skunk, flows from north to south on the east side of the city and then southeastward across Iowa to empty into the Mississippi River. Squaw Creek is a major tributary of the Skunk, entering the project boundary from the northwest and traversing the city until its junction with the Skunk just northwest of the intersection of two major highways (US-30 and I-35). In turn, a number of streams flow into Squaw Creek from the west: Onion Creek, Clear Creek, College Creek and Worrell Creek. Walnut Creek flows from west to east on the southern fringe of the project boundary and drains directly into the Skunk River southeast of the city.

Woodlands

The presence of "timber" and "grove" vegetation along streams and nearby uplands in Story County was documented during the Government Land Office (GLO) survey of Iowa conducted from 1832 to 1859. Timber and grove vegetation occupied about 8% of Story County at the time of this survey (Anderson 1996). Detailed information regarding the species composition of these categories is mostly lacking.

Ames woodlands (see Table 1 for definitions of natural area types) belong to the central hardwood forest region of the United States (Braun 1964). Three distinct woodland types exist in central Iowa: *xeric, mesic* and *floodplain* (Joens 1978, Johnson-Groh 1983, 1985).

Xeric woodlands are normally found on flat uplands, ridgetops and south- and west-facing slopes in central Iowa. *Quercus alba, Q. macrocarpa* and *Q. rubra* (= *Quercus borealis* var. *maxima*) are the typical canopy dominants of xeric woodlands, with *Ostrya virginiana* dominant in the understory (with lesser amounts of *Fraxinus* spp. and *Amelanchier arborea*).

Mesic woodlands are usually found on cooler and more moist north- and east-facing slopes in central Iowa. *Acer nigrum, Quercus rubra* and *Tilia americana* are usually dominant in the canopy, and *Ostrya virginiana* is again the understory dominant (with lesser amounts of *Carpinus caroliniana, Tilia americana, Acer nigrum,* and *Fraxinus* spp.).

At least two stages of floodplain vegetation can be readily identified in central Iowa. An early stage, found on streambanks and subject to frequent flooding, is dominated by *Salix nigra, Populus deltoides, Acer saccharinum* and *Acer negundo* in both canopy and understory. A later, more mature stage usually occurs on a terrace a short distance away from the river's edge and has *Juglans nigra, Carya cordiformis, Celtis occidentalis, Ulmus americana, Ulmus rubra, Fraxinus pensylvanica, Gleditsia triacanthos, Gymnocladus dioica,* and *Quercus macrocarpa* among its canopy dominants.

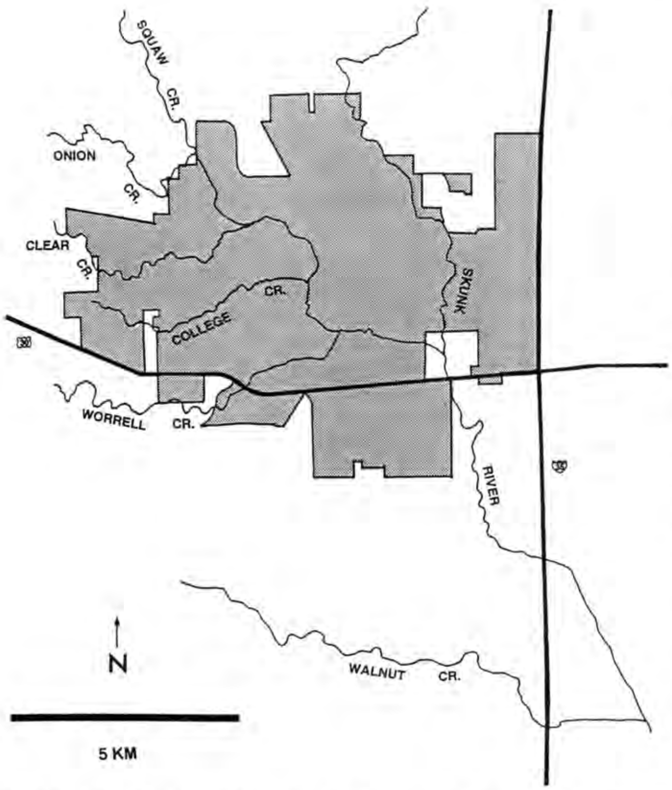

Fig. 1. Map of Ames, IA, showing corporate limits (5,957 ha) and major waterways.

Prairies

Prairie vegetation covered approximately 90% of Story County at the time of the GLO survey (Anderson 1996). A century later, Freckmann (1966) reported that perhaps five prairie remnants remained near Ames. In his survey of these remnants, Freckmann found 180 native prairie plant species. He noted that these remnants were remarkably diverse in character with at least five indicator species for each of five prairie types (wet, wet-mesic, mesic, dry-mesic, dry) occurring in Ames at that time.

Currently, at least eight native prairie remnants persist within two miles of the Ames city limits. These occur on dry knolls, open slopes, wetland margins and railroad rights-of-way in Ames.

Savannas

The term "savanna" has traditionally been applied to a wide range of wooded habitats with varying degrees of canopy closure. They have been characterized as having oak-dominated canopies with a mixture of prairie grasses and forbs in the understory (DeLong and Hooper 1996). Historically, *Quercus macrocarpa* is thought to have been the dominant tree of oak savannas in the midwestern United States (Burns and Honkala 1990 in DeLong and Hooper 1996).

Q. macrocarpa-dominated communities do occur in Ames. For example, mature stands of this species occur in the floodplain of the Skunk River. However, these are closed canopy forests, and the understory of these communities contains vegetation typical of floodplain forests, not prairie. Mature stands of *Q. macrocarpa* also occur on upland terrain in Ames, but in all such cases any native prairie species that may have been present have been essentially eliminated from the understory and ground flora by pasturing. Hence, we conclude that no savannas currently exist in Ames.

Wetlands

"Marsh" vegetation was documented as covering only about 1% of Story County during the GLO survey between 1832 and 1859, with the majority occurring in the northeast corner of the county (Anderson 1996). Although no marshes are documented as occurring in the vicinity of Ames (which is in the southwest corner of Story County), this may be due to alternate interpretations of wet prairie vegetation (i.e., "marsh", "prairie") by the different surveyors who worked in Story County during the survey.

The few wetlands that currently occur in Ames are properly referred to as prairie potholes, which are subject to seasonal inundation and drought cycles. Prairie potholes typically have their vegetation arranged in concentric circles which are referred to as *low prairie, wet meadow, shallow marsh, deep marsh* and *open water* zones. These wetlands are classified based on the vegetation found in the central or deepest zone (which is a measure of the permancy of water in that zone). The five wetland classes are: class I, *ephemeral ponds* with a central low-prairie zone; class II, *temporary ponds* with a central wet-meadow zone; class III, *seasonal ponds and lakes* with a central shallow-marsh zone; class IV, *semipermanent ponds and lakes* with a central deep-marsh zone, and class V, *permanent ponds and lakes* with a central permanent open water zone (Stewart and Kantrud 1971, 1972).

The most pertinent floristic study of wetlands specific to Story County is that of Wetzel et al. (1999) who conducted an inventory of Doolittle Prairie State Preserve (just north of the project boundary) in the 1990's. Their field work resulted in an extensive plant list for the preserve which serves as a baseline for the floras of other Story County wetlands.

NATURAL AREA EVALUATION

Evaluation of natural areas has been characterized as the process of "making measurements from a series of criteria and deciding which areas are most significant based on these measurements" (Smith and Theberge 1987). Evaluation is the term most frequently employed to describe the process of priority ranking of natural areas. This process has received much more attention abroad than in the United States, especially in England (Margules and Usher 1981, Usher 1985, Spellerberg 1992), the Netherlands (van der Ploeg and Vlijm 1978), Australia (Margules 1989) and New Zealand (O'Connor et al. 1990). American contributors to this literature include Tans (1974), Gehlbach (1975), Sargent and Brande (1976) and Swink and Wilhelm (1994). Excellent literature reviews of this topic can be found in Margules and Usher 1981, Usher 1985, Smith and Theberge 1986, 1987, and Spellerberg 1992.

Natural Area Evaluation in Iowa and the Midwest

White (1978) described an "intuitive" method of natural area evaluation that has been widely used. In his technical report for the Illinois Natural Areas Inventory, five grades of natural area quality are defined. These grades reflect the degree of disturbance that has occurred in a particular vegetation community. Much of this report is devoted to procedures for qualitatively detecting disturbance from both aerial and ground surveys of various natural communities on a case by case basis.

White's methodology was adopted by Duritsa (1983) in a natural area inventory of Black Hawk County (IA) which included evaluation of all woodlands. County woodlands were evaluated on the basis of percent canopy cover and on the canopy texture as seen on aerial photographs. Duritsa acknowledged that precise differentiation of "A" and "B" quality woodlands was at times difficult from aerial photographs, and that ground verification was often necessary to confirm "A" quality designations. She points out that (pp. 34–35):

. . .even under a heavily canopied area there may be uses, primarily pasturing, which obliterate ground strata. The designation of "B" could be particularly misleading because the system represents canopy conditions which are not necessarily indicative of the quality of the woodland community. Abandoned woodland pasture may have 90 percent or greater canopy cover, but this canopy cover could be comprised of "weed" trees such as hawthorne and honey locust to the exclusion of other native species. The aerial imagery used in this study does not allow for the identification of tree species.

Ground verification in Duritsa's method consisted of walking the entire site, recording plant species, noting fauna and signs of fauna (e.g., nests), and making a qualitative evaluation of the area based primarily on the vegetative composition.

A quantitative approach for evaluating natural areas quality based on plant species diversity was described by Swink and Wilhelm (1994) in their flora of the Chicago, Illinois region. In this work, each vascular plant in the flora has been assigned a numerical "coefficient of conservation" (C value) between 0 and 10 based on several factors, such as its relative abundance in the region as well as its relative fidelity to strict synecological conditions. To rate the quality of a particular natural resource, the evaluator simply surveys the flora there, computes the average C value of all plants found, and multiplies this by the square root of N (number of species encountered).

Pearson (1986) compiled a list of native prairie plant species in Iowa and assigned to each species a value (1 to 10) to be used in a "prairie quality index". These values for each species were determined by summing the scores of four components: rarity (R) reflecting statewide rarity (2, 5 or 8); disturbance (D) reflecting disturbance adaptability; fidelity (F) indicating fidelity to prairie communities (−1, 0 or 1); and a final bonus (B) category allowing for minor, intuitive adjustment of the overall score based on professional judgement of species value (0, 1 or 2). One could conceivably evaluate an Iowa prairie on the basis of these values using the procedure of Swink and Wilhelm (1994).

One of the first multi-criteria methods for the evaluation of natural areas was proposed by Tans (1974) for priority ranking of natural areas in Wisconsin. In Tans' scheme, points are allocated within four main categories: biological features, physical features, degree of threat and availability. Various subcategories are delineated within the biological features category (i.e., quality, commonness, community diversity, size and buffer) and scored separately. Tans advises that to evaluate an area, one needs merely to sum the points allocated for quality, commonness, community diversity, size and buffer. Then, this total and the points allocated for availability and threat can be compared among evaluated areas to facilitate their priority ranking.

Joens (1978) evaluated the quality of natural resources in Ames, Iowa that were used by Iowa State University as outdoor laboratories. In Joens' study, he described and assigned numbers to five levels of woodland quality. Although Joens acknowledged the earlier work of Tans (1974) as an influence on his rating system, their methods are in fact dissimilar because Joens does not explicitly allow for the separate evaluation of different criteria (e.g., diversity, structure, disturbance). In fact, Joens' approach is more similar to White's (1978) intuitive procedure for natural area evaluation in Illinois.

The purpose of this paper is to present an overview of the Ames Natural Areas Inventory. Included here is information regarding the history, goals, and cost of the inventory; a brief report of private landowner participation in the inventory; methodology developed for use in the field; examples of maps and site descriptions included in the final inventory document; and an account of how this document has been used since its acceptance by the City of Ames. We feel that the content of this paper will be of interest to a wide audience of scientists, city planners, county conservation board members and private citizens contemplating their own natural area inventory.

METHODS

The Ames Natural Areas Committee

In 1990, natural history experts with a variety of backgrounds were invited (by the Ames City Planning Office) to serve on the Ames Natural Areas Committee. The committee members were charged with exploring the possibility of conducting a natural area inventory of all lands within the jurisdiction of the Ames City Planning Office. The committee determined that an inventory of potential natural areas in the Ames region would have three purposes:

1) To identify, inventory and evaluate the *natural quality* of natural resource areas.
2) To define the values of natural areas to residents in the Ames area.
3) To recommend methods of protecting natural areas.

The initial task of the Ames Natural Areas Committee was to establish boundaries for inventory work to identify natural areas. On a large map of the Ames area made available by the Ames City Planning Office, a boundary line was drawn approximately two miles outside the corporate limits of the city to encompass a total area of 23,698 ha (58,557 ac). This two mile wide extraterritorial (fringe) area is that over which, by Iowa State law, municipalities may exercise control of subdivision regulation. Committee members then examined aerial photographs of land within the project boundary to identify known and potential natural areas. These areas were then outlined on the base map and tentatively classified as *woodland, prairie, wetland, streams* or *special resource.*

Before proceeding with the inventory, the committee prepared a formal set of definitions for the five natural resource types outlined on the project map (Table 1). Resource type designations and their definitions were designed specifically for maximum utility in the Ames area. These definitions do not conform to those used elsewhere; e.g., "woodlands" and "forest" are considered separately in the more complex community classification system of The Nature Conservancy (Drake and Faber-Langendoen 1997). Within these definitions, specific minimum parameters were established for each resource type. Definitions of these community types given by White (1978) were very useful models during this process. The Ames City Council approved the committee's definitions in late fall 1991.

Methods for the natural quality evaluation of prairies, woodlands and wetlands were developed for use in the Ames Natural Areas Inventory. The method developed for prairie evaluation is based on a single evaluation component: *species diversity* of native prairie plants (Table 2). Beyond occurrence of a minimal size, the prospect for restoration was considered the single most important criterion for evaluating prairie, and restorability was considered to be primarily a function of prairie species diversity. The method developed for woodland evaluation measures four components: *diversity* of expected species, *structure* of canopy and understory layers, *fidelity* of canopy dominants to the habitat type and absence of *introduced species.* Details of this method are presented below. A similar method was developed for wetland evaluation but was not implemented because only one sizeable wetland occurs in Ames, and it is already protected.

Woodland Evaluation

Forms developed for evaluating the natural quality of woodlands are presented in Table 3. *Natural quality* is here defined as the condition (species diversity, structural diversity, dominance patterns) of an existing vegetation community relative to that same community in the absence of recent (50 to 70 yr) major anthropogenic distur-

Table 1. Natural resource definitions for Ames, Iowa.

Prairie: An area of land in which any portion exceeding 500 square feet is more than 30% covered by, or contains at least 10 species of, naturally occurring plants native to Iowa prairie communities as recognized in the checklist of Iowa native prairie plants by the Iowa Department of Natural Resources Preserves and Ecological Services Bureau.

Wetland: An area of land in which any portion exceeding one acre is more than 50% covered by soil classified as wetland soil by the Soil Survey of Story County, and supports a plant community consisting primarily of native wetland plants as recognized in "A Checklist of the Aquatic and Wetland Vascular Plants of Iowa" (Lammers, T.G. and A.G. van der Valk, 1977, Proc. Iowa Acad. Sci. 84:41–88 and 1978, Proc. Iowa Acad. Sci. 85:121–163).

Woodland: An area of land exceeding one acre which supports 200 or more trees per acre, or has more than 50% canopy closure per acre, by trees native to Iowa as listed in Forest and Shade Trees of Iowa (van der Linden, P.J. and D.R. Farrar, 1993, Iowa State University Press, Ames, IA).

Streams: Waters that are free-flowing and support an ecosystem of native riparian plants and animals.

Special Resources: Areas or specimens that may not qualify as natural areas, but offer valuable recreation, education, cultural or biological resources. Examples might include but are not limited to the following:
a) tree plantations (of woodland size)
b) geological resources (e.g. gravel pits, rock quarries)
c) road rights-of way
d) railroad rights-of-way
e) rare species and unusual specimens (e.g. exceptionally large or old trees)

Table 2. Descriptions of natural quality levels for prairies in Ames, Iowa.

A. *Highly Natural.* Prairie with a high diversity of native prairie species[1] (at least 60 species).
B. *Mostly Natural.* Prairie with a good diversity of native prairie species (30–59 species).
C. *Moderately Altered.* Prairie with an average diversity of native prairie species (10–29 species).
D. *Highly Altered.* Prairie with a poor diversity of native prairie species (0–9).

[1]A "prairie species" is one included in a list of native prairie plants of Iowa compiled by John Pearson, Iowa DNR (1986).

bance (e.g., timber harvest, pasturing, introduced species). Our methodology relies on survey of the woody vegetation (trees, shrubs, vines) present in a woodland. Philosophically, our method is similar to the evaluation model developed by Tans (1974).

Our system utilizes 0.1 ha (18 m radius) circular plots. Plots of this size allow simultaneous view of the entire plot and are small enough to fit within the frequently small extent of topographic uniformity in central Iowa woodlands. Within these plots, four criteria are measured for both the canopy and the understory: *diversity* of expected woodland species, *structure* of canopy and understory layers, *fidelity* of dominant species to the habitat type, and absence of *introduced species.* For each criterion, a score of 2, 1 or 0 is assigned according to defined rules. The diversity component receives twice the weight of the other three criteria, and hence diversity scores are doubled before all scores are totaled to yield an overall woodland quality rating (WQR). The values yielded by this evaluation method range from 0 to 20 (20 represents the highest possible quality rating).

This woodland quality evaluation method assumes the existence of three major woodland types: xeric, mesic and floodplain. Establishing lists of expected canopy (trees) and understory (small trees, saplings, shrubs and vines beneath the canopy and at least 0.5 m above the ground) species for the three woodland types is integral to this evaluation method (Table 4). An "expected species" is one normally encountered in undisturbed (50 years or more) woodlands of the given type in central Iowa. The species lists are based on quantitative data collected from relatively undisturbed woodlands in nearby Ledges State Park in Boone County (Johnson-Groh 1983). Because subtle differences exist between woodlands in Ledges State Park and Ames, personal knowledge of Ames woodlands was used to modify these lists. For example, *Quercus muehlenbergii* is not uncommon in Ledges State Park, but occurs nowhere in Ames. *Carpinus caroliniana* was deleted from all understory lists when none was encountered during field work, and *Quercus velutina* was added to the canopy list for xeric woodlands after its discovery in Ames.

Diversity component. Species richness of expected species is used to measure the species diversity of both canopy and understory in this rating method. Prior to scoring this category, the woodland type being sampled (xeric, mesic or floodplain) must be determined. Only species expected to occur in the woodland type determined for the plot may be tallied when scoring this category (e.g., the occurrence of *Quercus alba* in a xeric woodland adds to canopy species richness, whereas the presence of *Gleditsia triacanthos* in this type does not). Thus, there is no increase in overall species richness due to invasion by floodplain species following a disturbance (e.g., tree cutting) that creates a large canopy gap on an upland site.

The choice of woodland type for the plot is restricted by topography as follows: xeric for all ridgetops; xeric or mesic for all slopes; and mesic or floodplain for all bottomlands. With these restrictions in mind, inspection of canopy dominants within the plot and subsequent referral to the lists of expected canopy species for each woodland type (Table 4) usually indicates the type. If the choice is not clear from the dominant canopy species, then the woodland type which gives the highest score for canopy diversity (while adhering to the above topographic restrictions) is selected.

Joens (1978) noted that the mesic type, dominated by *Acer nigrum* and *Tilia americana,* is less diverse than either xeric or floodplain woodlands. This pattern was also observed in this study. For example, in 0.1 ha circular plots in Ames woodlands, species richness of expected canopy trees rarely exceeds 4 in the best of mesic sites. On the other hand, the average or common number was found to be about 5 tree species for xeric plots and 10 tree species for floodplain plots. These common "diversity targets" of expected species richness in 0.1 ha plots are considered to be the norm against which sample plots are evaluated. A much lower number of expected species for a given woodland type and stratum results in a lower score (see Table 3). Diversity targets are given in Table 4 for both canopy and understory of all three woodland types.

A special exception to the usual rules for scoring canopy diversity is made in xeric woodlands where the canopy is a monodominant stand of either *Quercus alba* or *Quercus macrocarpa.* Complete canopy dominance by these species is not unusual and may have resulted from natural processes and thus should not be penalized. Therefore, when this condition is encountered in xeric plots an intermediate score ("1") is rewarded by default for canopy diversity rather than the "0" called for by strict application of the rules.

Structure component. This category is scored on the basis of estimated

Table 3. Method for evaluation of woodlands in Ames (Iowa).

A) *Diversity*[1]
2 Possesses at least 75% of the "diversity target" of species expected in the woodland type.
1 Possesses between 50% and 75% of the "diversity target" of species expected in the woodland type.
0 Possesses less than 50% of the "diversity target" of species expected in the woodland type.[2]
____ canopy
____ understory
DV = ____ (sum of scores)

B) *Structure*
i) Canopy
2 Over 75% total canopy cover
1 At least 50% but less than 75% total canopy cover
0 Less than 50% total canopy cover
ii) Understory
2 Between 40% and 80% total understory cover
1 At least 20% and less than 40% total understory cover
OR
Greater than 80% total understory cover primarily due to small trees and saplings (dbh > 5 cm).
0 Less than 20% total understory cover
OR
Greater than 80% total understory cover primarily due to shrubs and vines (dbh < 5 cm).
____ canopy
____ understory
S = ____ (sum of scores)

C) *Fidelity*[3]
2 Greater than 75% of the cover is provided by species representative of woodland types typically found in the given aspect.
1 Between 25% and 75% of the cover is provided by species representative of woodland types typically found in the given aspect.
0 Less than 25% of the cover is provided by species representative of woodland types typically found in the given aspect.
____ canopy
____ understory
F = ____ (sum of scores)

D) *Introduced Species*
2 Species not native to central Iowa woodlands are absent or not conspicuous (less than 1% cover).
1 Species not native to central Iowa woodlands are conspicuous but not dominant (between 1% and 15% cover).
0 Species not native to central Iowa woodlands are very conspicuous to dominant (greater than 15% cover).
____ canopy
____ understory
I = ____ (sum of scores)

$$WQR = 2*DV + S + F + I$$

The value of WQR (woodland quality rating) will range from 0 to 20, with 20 representing the highest quality

[1]When scoring the diversity category for woodlands found on *ridgetops,* assume *xeric* to be the proper woodland type.

When scoring the diversity category for woodlands occurring on *slopes* choose *xeric* or *mesic* as the woodland type by comparing the dominant canopy tree species in the plot to the lists of expected tree species for each woodland type as a guide (Table 4). If the woodland appears to be intermediate between these two types, choose the type which yields the highest canopy diversity score.

When scoring the diversity category for woodlands found on *bottomlands,* choose *floodplain* or *mesic* as the woodland type by comparing the dominant canopy species in the plot to the lists of expected tree species for each woodland type as a guide (Table 4). If the woodland appears to be intermediate between these two types, choose the type which yields the highest canopy diversity score.

Once the woodland type has been determined, only species characteristic of that type shall be considered when scoring the diversity category (see Table 4)

[2]The canopy of any xeric woodland that is strongly dominated (greater than 75% canopy cover) by *Quercus macrocarpa* or *Quercus alba* shall receive a score no lower than 1 in the diversity category.

[3]*Xeric* types are typically found on *ridgetops*; *xeric* and/or *mesic* types are expected on slopes; and *mesic* and/or *floodplain* types typically occur on bottomlands. See Table 4 for lists of expected species for each woodland type.

When representative species of several woodland types occur together in a given sample, consider the total cover of species from both types when scoring the fidelity category IF both woodland types are typical of the given aspect

total percent cover by canopy and understory elements. The rules for evaluating the structure of the canopy and the understory differ somewhat (Table 3).

Canopy structure is evaluated in a straightforward fashion, with maximum points awarded when total canopy cover is highest (at least 75%). Conversely, any plot falling in a woodland where total canopy cover is less than 50% receives no points for canopy structure. Note that an area with less than 50% canopy cover overall is not considered to be a woodland (Table 1).

Ideal understory structure is assumed to occur when total cover by saplings, shrubs and vines form a random, mosaic pattern beneath the canopy (at least 40% but no more than 80% cover). Small canopy gaps due to intermittent natural disturbance (e.g., windthrow, senescence of old trees) could conceivably produce this pattern. When understory cover is greater than 80%, unnatural past disturbances (e.g., grazing, logging) are inferred and fewer points are rewarded for understory structure. Dense understory cover hinders light penetration to the forest floor and limits the growth of woodland herbs. Dense cover primarily due to saplings and small trees (dbh at least 5 cm) is assumed to be less severe than dense cover by shrubs (dbh less than 5 cm) in a woodland. Hence, a score of "1" is awarded in the former case, while a "0" results when the understory is overgrown with shrubs.

Fidelity component. Woodland types are typified by certain characteristic dominant species. Human disturbance (e.g., logging and grazing practices; introduction of exotic species) alter natural dominance patterns in a given woodland type in a variety of ways, and the result is often an alteration in the degree of dominance exetted by the expected species.

The fidelity component measures whether or not the observed canopy and understory dominants are those listed as expected for the topography of a sample point. For example, on a ridgetop one expects to find xeric vegetation in the canopy and understory (Table 3). When a majority (at least 75%) of the canopy cover on a wooded ridgetop is provided by tree species expected for xeric woodlands a maximum score (2 pts) is awarded. On the other hand, whenever less than 25% of total canopy cover is formed by expected tree species, no points are awarded for canopy fidelity.

Table 4. Lists of expected woody species for xeric, mesic and floodplain woodland types in Ames, IA. Diversity target is the expected species richness of canopy or subcanopy for a given woodland type (0.1 hectare circular plot).

A) Xeric Woodlands (Typically encountered on ridgetops, south- and west-facing slopes)

Expected Canopy Species: Xeric
(Diversity Target = 5)

Carya ovata (Shagbark Hickory)
Fraxinus americana (White Ash)
Populus grandidentata (Big-toothed Aspen)
Prunus serotina (Black Cherry)
Quercus alba (White Oak)
Quercus rubra (Red Oak)
Quercus macrocarpa (Bur Oak)
Quercus velutina (Black Oak)

Expected Understory Species: Xeric
(Diversity Target = 10)

Acer nigrum (Black Maple)
Amelanchier arborea (Downy Serviceberry)
Carya cordiformis (Yellowbud Hickory)
Carya ovata (Shagbark Hickory)
Cornus spp. (Dogwood)
Corylus americana (Hazelnut)
Euonymous atropurpurea (Wahoo)
Ostrya virginiana (Ironwood)
Parthenocissus quinquefolia (Virginia Creeper)
Populus grandidentata (Big-Toothed Aspen)
Prunus serotina (Black Cherry)
Prunus virginiana (Choke Cherry)
Tilia americana (American Basswood)
Quercus spp. (Oak)
Viburnum lentago (Nannyberry)
Viburnum rafinesquianum (Downy Arrowwood)
Vitis riparius (River Grape)

B) Mesic Woodlands (Commonly encountered on north- and east-facing slopes; uncommonly in bottomlands).

Expected Canopy Species: Mesic
(Diversity Target = 4)

Acer nigrum (Black Maple)
Carya cordiformis (Yellowbud Hickory)
Fraxinus nigra (Black Ash)
Juglans cinerea (Butternut)
Quercus rubra (Red Oak)
Tilia americana (American Basswood)

Expected Understory Species: Mesic
(Diversity Target = 8)

Acer nigrum (Black Maple)
Amelanchier arborea (Downy Serviceberry)
Carya cordiformis (Yellowbud Hickory)
Corylus americana (Hazelnut)
Cornus alternifolia (Pagoda Dogwood)
Cornus spp. (Dogwood)
Euonymous atropurpurea (Wahoo)
Fraxinus nigra (Black Ash)
Fraxinus spp. (Ash)
Juglans cinerea (Butternut)
Menispermum canadense (Moonseed)
Morus rubra (Red Mulberry)
Ostrya virginiana (Ironwood)
Parthenocissus virginiana (Virginia Creeper)
Quercus spp. (Oak)
Staphylea trifolia (Bladdernut)
Tilia americana (American Basswood)
Viburnum rafinesquianum (Downy Arrowwood)
Vitis riparius (River Grape)

C) Floodplain Woodlands (Commonly encountered in bottomlands)

Expected Canopy Species: Floodplain
(Diversity Target = 10)

Acer negundo (Box Elder)
Acer saccharinum (Silver Maple)
Carya cordiformis (Yellowbud Hickory)
Celtis occidentalis (Hackberry)
Fraxinus nigra (Black Ash)
Fraxinus pennsylvanica (Green Ash)
Gleditsia triacanthos (Honey Locust)
Gymnocladus dioica (Kentucky Coffee Tree)
Juglans cinerea (Butternut)
Juglans nigra (Black Walnut)
Platanus occidentalis (Sycamore)
Populus deltoides (Cottonwood)
Quercus macrocarpa (Bur Oak)
Salix nigra (Black Willow)
Ulmus americana (American Elm)
Ulmus rubra (Red Elm)

Expected Understory Species: Floodplain
(Diversity Target = 15)

Acer nigrum (Black Maple)
Acer negundo (Boxelder)
Acer saccharinum (Silver Maple)
Carya cordiformis (Yellowbud Hickory)
Celtis occidentalis (Hackberry)
Cornus alternifolia (Pagoda Dogwood)
Cornus spp. (Dogwood)
Euonymous atropurpurea (Wahoo)
Fraxinus nigra (Black Ash)
Fraxinus spp. (Ash)
Gleditsia triacanthos (Honey Locust)
Gymnocladus dioica (Kentucky Coffee Tree)
Juglans cinerea (Butternut)
Juglans nigra (Black Walnut
Menispermum canadense (Moonseed)
Morus rubra (Red Mulberry)
Ostrya virginiana (Ironwood)
Parthenocissus virginiana (Virginia Creeper)
Platanus occidentalis (Sycamore)
Populus deltoides (Cottonwood)
Quercus spp. (Oak)
Rubus spp. (Black Raspberry, Blackberry)
Salix spp. (Willow)
Sambucus canadensis (Common Elderberry)
Smilax hispida (Greenbriar)
Staphylea trifolia (Bladdernut)
Tilia americana (American Basswood)
Toxicodendron radicans (Poison Ivy)
Ulmus spp. (Elm)
Viburnum rafinesquianum (Downy Arrowwood)
Vitis riparius (River Grape)

Both xeric and mesic woodland types normally occur on sloping terrain. The work of Johnson-Groh (1983, 1985) suggests that these types form a continuum graded by slope aspect (the most xeric woodlands on south- and west-slopes; the most mesic woodlands on north and east-facing slopes) in central Iowa. The existence of this gradient causes problems in scoring of the fidelity component on sloping terrain. First, there is the problem of northwest- and southeast-facing slopes: neither of the extremes clearly belongs here to the exclusion of the other. Second, soil moisture (and mesic-xeric character) can be affected by other factors such as valley width and subsoil drainage as well as aspect. Thus, for example, good quality mesic woodlands in Ames sometimes occur on west-facing slopes. To accomodate these problems, we consider any combination of mesic and xeric vegetation on a slope to be appropriate when scoring this category, regardless of the slope aspect. The presence of floodplain vegetation, however, is considered unnatural on a mature woodland slope.

In the absence of disturbance, floodplain vegetation in central Iowa bottomlands is normally replaced by vegetation more characteristic of mesic slopes. Thus, mixtures of these two woodland types are also considered valid when scoring the fidelity component of bottomlands.

Introduced species component. Obviously, the conspicuous presence of plant species not native to central Iowa woodlands reduces a woodland's natural quality. Introduced species include not only exotic trees and shrubs native to Eurasia (e.g., *Ulmus pumila, Lonicera maackii, Lonicera tartarica, Morus alba, Rhamnus cathartica, Rosa multiflora*) but also several tree species that occur naturally in the U.S. (e.g., *Pinus strobus, Robinia pseudoacacia*) but are not native to central Iowa woodlands. Percent cover by introduced species within the sample plot provides the basis for scoring this component, and the scoring rules are straightforward (Table 3).

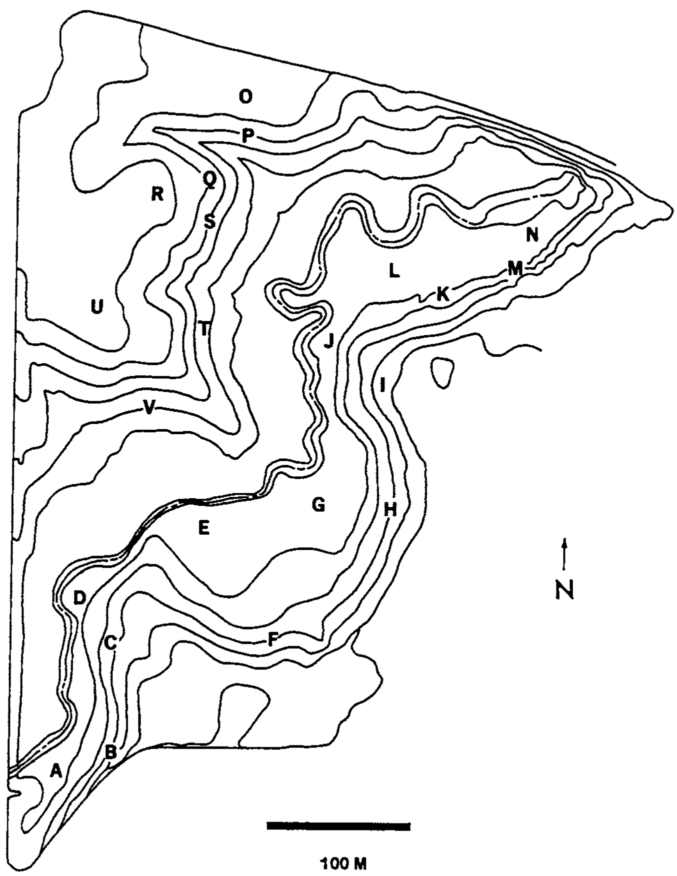

Fig. 2. Topographic map of Pammel Woods (Ames, IA) with sample points marked prior to field work.

Woodland Survey Protocol

Maps. Prior to field work, topographic maps of all wooded tracts were prepared from topographic maps available from the Ames City Planning Office. The originals have a 1:12000 scale and were created in the 1950s and early 1960s. Hence, they accurately depict the topography of regions in Ames but they are often not accurate with respect to road systems and landmarks.

Some regions of the project boundary were not covered by these city planning maps. In these instances 1:24000 USGS topographic maps were used.

Sample points. To apply the evaluation method, sample points were marked and labeled on a topographic map of the area in question prior to actual field work such that all topographic aspects were represented (Fig. 2). The sample points were circular (area: 0.1 ha; radius: 18 meters) and their number was established in rough proportion to the area of the tract. The center and the boundary of the plot (in each of the four cardinal directions) was flagged to allow for accurate and consistent censusing.

Data forms. Survey data were recorded on field forms. Total canopy (canopy trees) and understory (saplings, shrubs, twining vines) cover were estimated using cover classes (<1%, 1–24%, 25–50%; 50–75%; 75–100%). All woody plant species occurring in the canopy and understory inside the plot were listed along with their estimated percent cover (as cover classes) within the plot. Using all the data recorded on the form, the quality of the woodland at a particular sample point was calculated in the field immediately after the survey. Total survey time per point ranged from 15 to 30 min, with high quality floodplain vegetation taking the longest time because of their high diversity.

Quality Levels

Four levels of woodland quality were recognized: A) Highly Natural, B) Mostly Natural, C) Moderately Altered and D) Highly Altered. Written descriptions of each quality level were based on the degree of naturalness exhibited by both canopy and understory of a woodland as well as the amount of past disturbance (i.e., logging, grazing) experienced by the woodland (Table 5).

Based on examination of numerical quality ratings obtained in evaluations of woodlands falling into these four categories, the range of possible quality ratings (0–20) was subdivided into four intervals and associated with the above quality levels (Table 5).

Final Maps and Descriptions of Woodlands

The quality ratings obtained during field work were marked on topographic maps of each tract (Fig. 3), which were then used to delineate different quality regions within a given woodland. Regions were identified by aggregation of numbers in the same quality level on the map or by averaging of quality values when trends were not clear. Different quality regions were then outlined with a black marker on a third map of each region and identified by letters corresponding to each quality level (Fig. 4).

Written descriptions in layman's terms were prepared to accompany each map (Table 6). Any unusual flora and/or fauna observed during field work in a particular woodland was included in this written description.

Table 5. Descriptions of natural quality levels for woodlands in Ames, Iowa.

A. *Highly Natural.* Undisturbed natural woodlands composed of the expected diversity of native species (WQR = 18, 19 or 20).

Example: Old growth, ungrazed forest

B. *Moderately Natural.* Lightly disturbed woodlands in which both overstory and understory are predominately composed of species expected under natural conditions (WQR = 14, 15, 16 or 17).

Example: Woodlands that have been selectively logged or grazed without destroying the structure and natural diversity.

C. *Moderately Altered.* Disturbed woodlands in which either the overstory or the understory is not predominately composed of species expected under natural conditions (WQR = 10, 11, 12 or 13).

Example: Woodlands in which the understory and ground cover have been altered by grazing or recreation.

D. *Highly Altered.* Heavily disturbed woodlands in which neither the overstory nor the understory is predominately composed of species expected under natural conditions (WQR = 0, 1, 2, . . . , 9).

Example: An upland woods in which the overstory and the understory have developed following severe recent disturbance.

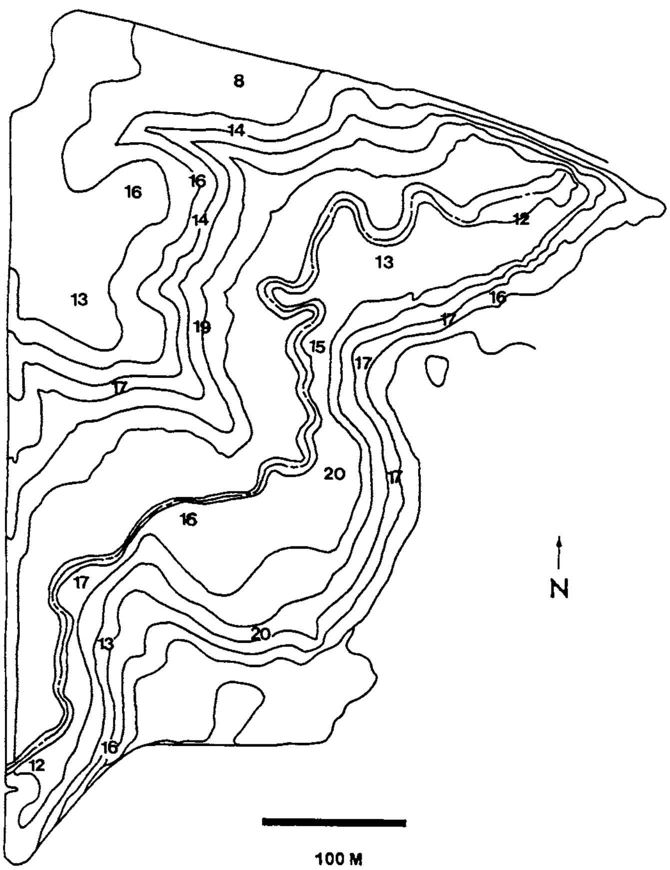

Fig. 3. Topographic map of Pammel Woods (Ames, IA) with woodland quality ratings (0–20) marked at sample points after survey.

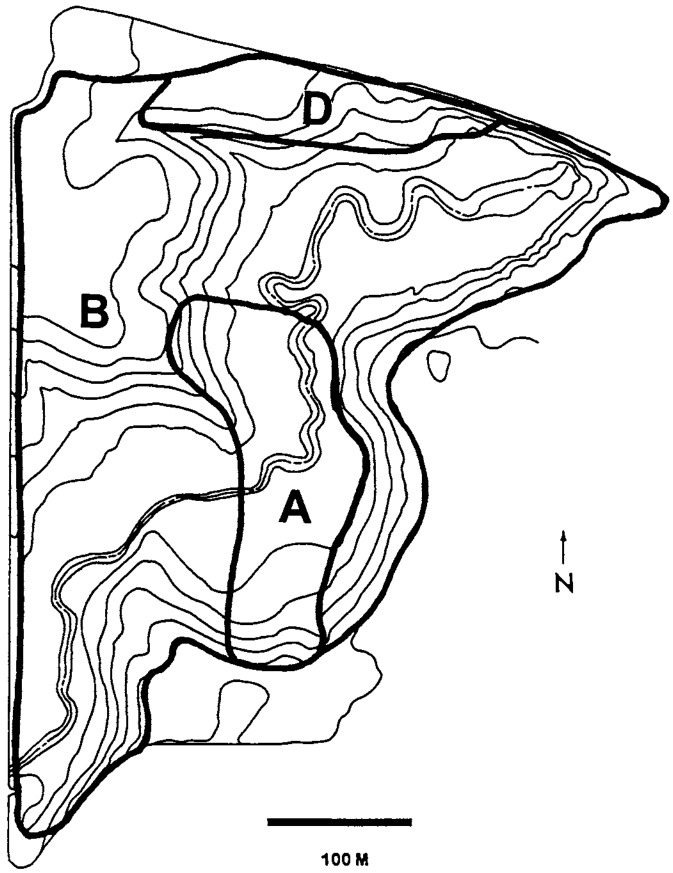

Fig. 4. Topographic map of Pammel Woods (Ames, IA) with woodland quality regions delineated. A = Highly Natural; B = Mostly Natural; C = Moderately Altered; D = Highly Altered.

RESULTS

Acreage of Evaluated Areas

Field work for the inventory was conducted in 1992 and 1993. A total of 928 ha (2,294 acres) was classified (Table 7) and described in the inventory report submitted to the Ames City Planning Office in the fall of 1994. This represents 3.9% of the total area (23,698 ha) encompassed by the boundary established for this inventory. Of this, 595 ha was surveyed on foot and determined to be either "Highly Natural", "Mostly Natural", "Moderately Altered" or "Highly Altered." Another 333 ha were classified without on-site survey via personal knowledge of the committee members as either "Altered", "Special Resource" or "Permission Lacking." "Altered" sites were known via personal knowledge of the committee members to be severely impacted by human activity (i.e., grazing and/or tree cutting) and hence unworthy of survey given the time constraints established for completion of the inventory. "Special Resource" areas were acknowledged to have important value to Ames citizens despite significant departures from "naturalness." These include prairie reconstructions, city parks and private holdings modified to accomodate recreational activity (e.g., Izaak Walton League property).

Of the total 928 ha classified during the inventory, only 66 ha (7% of total classified) were evaluated to be "Highly Natural." This represents 0.28% of the land area contained within the inventory boundary. On the other hand, 433 ha (47% of total classified) were evaluated as "Altered", "Moderately Altered", or "Highly Altered."

Table 6. Sample of a written description of woodland (Pammel Woods) surveyed during the Ames Natural Areas Inventory.

Pammel Woods

The majority of Pammel Woods is a rich woodland. On most slopes and a flat ridgetop located in "B" level regions, white, red and bur oaks, black maple and basswood are the dominant canopy trees; ironwood and black maple saplings are dominant in the understory. An introduced shrub (European buckthorn) is conspicuous here and there in the understory, but the majority of the vegetation is natural.

A rich bottomland forest occurs along Clear Creek as it winds its way through Pammel Woods. Both the canopy and the understory of this region ("A" quality level) contain a high diversity of species typical of bottomlands. The floodplain forest bordering the "A" quality region on either side is similar but contains less diversity of typical tree species, and introduced shrubs (*i.e.* white mulberry, Tartarian honeysuckle, European buckthorn) occasionally become dominant in the understory.

A small strip of unnatural vegetation ("D" quality level) occurs on the north end of Pammel Woods, bordering the railroad. An introduced tree (black locust) and a shrub (European buckthorn) are dominant in the woodland here.

The majority of Pammel Woods contains a rich carpet of native wildflowers from spring through fall, and it serves as a laboratory for many botany classes at ISU. An uncommon plant, green dragon (*Arisaema dracontium*), is among the many wildflowers found in Pammel Woods.

Table 7. Total land area (ha) of all natural quality categories identified during the Ames Natural Areas Inventory (1991–1994).

Surveyed Land (SL)

CATEGORY	AREA	% OF TOTAL SL	% OF OVERALL TOTAL
Highly Natural	66	11	7
Mostly Natural	231	39	25
Moderately Altered	204	34	22
Highly Altered	94	16	10
Total Surveyed Land	595		64

Unsurveyed Land (UL)

CATEGORY	AREA	% OF TOTAL UL	% OF OVERALL TOTAL
Altered	135	41	15
Special Resource	70	21	8
Permission Lacking	128	39	14
Total Unsurveyed Land	333		36
OVERALL TOTAL	928		

If the 128 ha of land where permission to survey was denied is assumed to be pastured woods (as it appears from accessible viewpoints), then 561 ha (61% of the overall total) would be classified as altered to some extent.

Both public and private lands were surveyed during this inventory. Of the approximately 50 private landowners contacted during the inventory, 46 (92%) consented to a survey and natural quality evaluation of their property.

The Ames City Council voted to accept the final inventory report in December 1994. This inventory was funded jointly by the City of Ames ($15,000), Iowa State University ($10,000) and the Iowa Science Foundation ($4,694) with a total cost, including contributed services by the City, of approximately $30,000.

Maps, Written Descriptions and Plant Species Lists

Maps and written descriptions of all surveyed sites as well as most "Special Resources" were prepared (Norris 1995). For large diverse sites surveyed on foot, three maps were prepared: one delineating the different quality regions for the site, another that displays the quality ratings associated with all survey points within a site, and a third that identifies the dominant vegetation at each survey point within a site. Few of the surveyed prairie remnants were sufficiently large or diverse to warrant mapping, but lists of all prairie plant species found on each remnant during the inventory were compiled.

Cumulative checklists of all plant species found in the survey of Ames woodlands, prairies and wetlands during the course of the Ames Natural Areas Inventory (1991–1994) were compiled. These lists do not include historic records or species reported but not vouchered by other individuals during this same time interval. A total of 493 plant species (408 native) were recorded during the inventory. One federally endangered plant, prairie bush clover (*Lespedeza leptostachya*), was documented in a prairie remnant during the inventory. Additionally, a state-endangered species, oval ladies' tresses (*Spiranthes ovalis*), was found in disturbed woods, and a species of special concern in Iowa, Great Plains ladies' tresses (*Spiranthes magnicamporum*), was discovered in a prairie remnant. This list will be published later in an analysis of the Ames flora currently in preparation.

DISCUSSION

The "Science" of Quality Evaluation

The quality evaluation of natural areas unavoidably includes subjective aspects (Margules and Usher 1981, Swink and Wilhelm 1994). Although the evaluation components (species diversity, structural diversity, area of tract, etc.) incorporated by a particular evaluation method may be justified ecologically, their very selection from a larger pool of possible evaluation components adds a degree of arbitrariness to the method. The weighting of components, the aggregation of component scores into a quality index, and the ultimate delineation of different quality regions within an evaluated area are also somewhat arbitrary processes. Nonetheless, quality evaluation of natural areas is reasonable provided that i) the evaluation components are justified biologically, ii) objective sampling methods are used where possible and iii) all subjective decisions that enter into evaluation are carefully thought out and explicitly stated.

Definition of Quality

Quality concepts vary among individuals and thus among inventories. To illustrate, one need only compare the Pammel Woods quality map produced in this inventory (Fig. 4) with that presented by Joens (Fig. 5) in his earlier study of Ames natural areas (1978). Although there is reasonable congruence in the quality determined

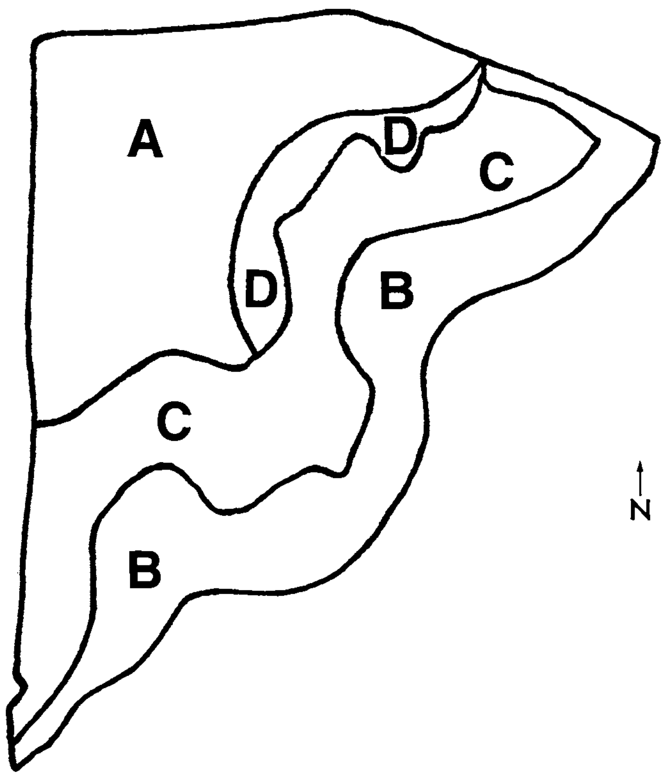

Fig. 5. Quality regions within Pammel Woods as delineated by Joens (figure 4, 1978). Regions A, B and D are high quality; region C is low quality.

for the upland woods, considerable discrepancy occurs between the qualities given for the floodplain. Joens (1978) considered all of these bottomland woods to be of low quality in Pammel Woods (Fig. 5) because in his view any woodland type maintained by a disturbance (e.g., floodplain vegetation) has inherent low quality. On the other hand, floodplain woods resulting from natural disturbances received a higher quality evaluation within the quality concept adopted for this inventory (Fig. 4). Thus, it is important that the term "quality" be carefully defined wherever it is used as the basis for natural area evaluation. As applied to woodlands in this inventory, quality refers to the condition of a woodland relative to what might be expected from natural processes in the absence of recent human-induced disturbances. Several aspects of this definition merit further discussion.

Species composition. There is considerable debate concerning the natural vegetation of a mature woodland occurring on dry ridgetops (and dry slopes) in central Iowa. Currently, one finds *Quercus* spp. and *Carya ovata* dominant in the canopy of such woodlands, but small trees and saplings of these same species seldom occur in the understory. Some researchers believe that historically recurring ground fires opening the understory and repressing fire intolerant species were important in maintaining oak dominance (Abrams 1992). Others believe that broad-scale canopy clearing disturbances were also necessary for intolerant *Qurcus* and *Carya ovata* seedlings to become established in the past by opening up the canopy (Williams 1989). There is now concern that *Acer nigrum, Tilia americana* and other shade tolerant species are becoming dominant in the canopy of currently oak-dominated woodlands because current fire suppression allows growth of these species and is forestalling the regeneration of oak and shagbark hickory. Other evidence suggests that oaks and shagbark hickory will continue to be the canopy dominants on dry ridgetops in central Iowa because they are better adapted than *Acer nigrum* and *Tilia americana* to tolerate the occasional severe droughts experienced in central Iowa (Johnson-Groh 1985).

The natural species composition in a central Iowa bottomland is also not straightforward. Although typical floodplain species like *Juglans nigra* and *Celtis occidentalis* are usually the canopy dominants here, *Acer nigrum* and *Tilia americana* are occasionally found to be the dominants in this habitat. It is our perception that canopy dominance in a bottomland is controlled by frequency of disturbance, with *Acer nigrum* and *Tilia americana* appearing in the understory and becoming increasingly dominant on bottomland terraces where disturbance has not recently occurred.

Obviously, the frequency of disturbances (fire, drought, flooding) affects the dominance patterns of vegetation in a woodland. In our use, woodland quality refers primarily to presence of a canopy of mature trees of species expected at some stage of *natural* succession following *natural* disturbance. Therefore, a bottomland terrace dominated by large trees of typical bottomland species (e.g., *Juglans nigra, Celtis occidentalis*) is considered just as natural as a bottomland terrace dominated by large *Acer nigrum* trees, even though *Acer nigrum* may eventually succeed the bottomland species in the absence of disturbance. On the other hand, domination of an upland site by "bottomland" species, even though mature, is almost always the result of anthropogenic disturbance and is thus not natural.

Diversity standards. The current structure and species composition of woodlands in Ledges State Park in adjacent Boone Co. were used as standards for the highest diversity likely to be displayed by Ames woodlands. Woodlands in Ledges State Park were harvested at the turn of the century but those in the original park have been undisturbed since park designation in 1924. The continual presence of a high species diversity, including many disjunct occurrences of eastern and northern species, indicates that the natural diversity of Ledges persisted through historic prairie expansion as well as through early European disturbance (Johnson-Groh and Farrar 1985). Because the topographic relief of Ledges State Park is greater than in Ames, and the park borders a larger river (Des Moines River), the woodlands of this park (minus those species not occurring in the Ames area) present a reasonable standard for woodland development in the Ames area.

Comparison with Other Evaluation Methods

Plant species diversity figures prominantly in the explicit evaluation method presented by Swink and Wilhelm (1994). Their approach requires complete floristic knowlege of a region, as well as the objective assignment of "coefficients of conservation" to the species in that flora. Because these data have not been assembled for central Iowa, it was not feasible to implement Swink and Wilhelm's method for evaluation of woodlands for the Ames Natural Areas Inventory or to compare results with our method.

Intuitive methods (e.g., White 1978) are useful when applied by professional biologists who are experts in the natural history of a region. An experienced observer, intimately familiar with the various natural resource types, would certainly be able to employ such methods and evaluate natural areas. However, an "intuitive" approach requires professional-level experience on the part of the surveyer. Furthermore, it contains subjectivity and is thus susceptible to challenge by land developers, city councilmen, lawyers, etc. In contrast, the methodology presented in this paper is explicit. It is usable by entry-level and experienced biologists alike. The only prerequisite is that the potential evaluator have good woody plant identification skills.

The woodland evaluation method presented in this paper is similar to Tans'(1974) scheme for natural area evaluation. Both methods call for the measurement of several ecological components whose weight-ed scores are then summed to yield a single quality rating for an evaluated site. In Tans' method, the rules for scoring the criteria are stated conceptually, leaving an evaluator to determine in his/her own mind how to actually assign points for a given component. In contrast, the current method for evaluation of woodland quality uses explicit rules for the scoring of four evaluation components (*diversity, structure, fidelity,* absence of *introduced species*) within a 0.10 hectare survey point (Table 3, 4).

Unresolved Problems

Unanticipated problems with the use of an evaluation method are sure to arise in the field no matter how carefully one states the rules for measuring the criteria of the method on paper. Any method must recognize the potential for alterations to improve its effectiveness on future application to the same or new areas. Possible alterations of this method are discussed below.

a) Evaluation of woodland structure. As written, the rules for evaluating woodland structure presuppose the existence of distinct canopy and understory layers in a woodland. Although these foliage layers are easily recognized in mature woodlands, some woodlands lack a well-defined canopy. For example, even-aged stands of *Acer negundo* and/or *Ulmus* spp. often occur in young woodlands developed on abandoned cropfields. Evaluating the structure of these young woodlands is difficult because clear canopy and understory layers are undifferentiated. A possible solution to this problem would be to deduct points for the absence of distinct canopy and understory layers.

No explicit definitions of "canopy" and "understory" were established during this inventory. The latter category was interpreted to encompass all woody vegetation at least 0.5 m tall and beneath the canopy. Thus, tall ironwoods (*Ostrya virginiana*) many meters high are lumped together with low shrubs (e.g., *Ribes* spp.) that have no potential to become trees. An alternative would be to evaluate two woody understory strata separately: a *subcanopy* of small trees and tree saplings and a *shrub* layer of low woody vegetation with no potential to become trees. This may be a biologically significant division because certain forms of wildlife (e.g., forest songbirds) are influenced by the presence or absence of three forest layers when selecting habitat (MacArthur and MacArthur 1961).

b) Interdependence of evaluation criteria. A degree of interdependence of many, if not all ecological evaluation criteria can not be denied. In the current woodland evaluation method, the "fidelity" and "introduced plants" components seem particularly intertwined. For example, consider a recently grazed ridgetop woodland in which the understory is dominated by an introduced (and unexpected) shrub, *Lonicera tatarica.* Minimum scores result for both of the above categories when they are evaluated according to the current rules (Table 3). If the understory of this same woodland was dominated by an unexpected species such as American elm (*Ulmus americana*), a minimum score would result in the fidelity but not in the introduced species category because American elm is a species native to central Iowa. Evaluators uncomfortable with this double penalty for dominance by introduced species could choose not to include the "Introduced Species" component when developing their own methodologies.

c) Herbaceous quality. The most obvious omission among the criteria used in the adopted method for woodland evaluation is an appraisal of the herbaceous layer. A mature, not recently disturbed woodland typically contains a different herbaceous flora than a recently disturbed (i.e., grazed, logged, flooded) woodland. Disturbances such as grazing and flooding often remove many perennial herbs characteristic of mature woodlands. Furthermore, woodland wildflowers are frequently shaded out by a dense thickets of low shrubs that typically occurs in recently grazed and/or logged woodlands. One usually encounters opportunistic weed species in the herb layer of a recently disturbed woodland as well as unnatural dominance by a few persistent herbs typical of mature woodlands (e.g., *Laportea canadensis, Galium aparine*). Obviously, the species composition and dominance patterns observed for the herbaceous layer in a woodland can shed much light on the past history (and hence the quality) of the woodland.

Consideration of the herbaceous layer (e.g., diversity of expected species, herbaceous cover, absence of introduced species) in woodland evaluation would likely have enhanced the ability of the method to discriminate between different quality woodlands. However, inclusion of herbaceous plants also introduces severe limitations to the practicality of large scale woodland evaluation.

Woodland wildflowers are not all evident nor easily identified at the same time of year. For example, the Dutchman's breeches (*Dicentra cucullata*) and spring beauties (*Claytonia virginica*) of late April and May disappear by mid-summer, most woodland sedges (*Carex* spp.) can be identified only when they produce mature fruit in June, and woodland goldenrods (*Solidago* spp.) and asters (*Aster* spp.) don't flower until late summer and thus are difficult to identify until that time. To determine the total species richness of the herbaceous layer in each woodland, two or three herbaceous surveys at different times of the year are necessary. Given hundreds of woodland acres needing survey, such an intense survey was not practical during this inventory.

Density of ground cover by woodland herbs also varies seasonally. The colorful carpet of false rue anenome (*Isopyrum biternatum*) and dog-tooth violet (*Erythronium albidum*) that blankets a wooded slope in spring will have disappeared by mid-summer. This phenomenon also occurs in reverse; the forest floor of a bottomland that is naked in May may be filled with wood nettle (*Laportea canadensis*) by mid-July. If herbaceous cover were an evaluation component, one would have to choose one or several dates, then survey all woodlands in the same short time intervals to avoid phenological differences.

Although survey of woodland herbs for evaluation purposes is highly desirable and indeed possible (Peterken 1977, Goodfellow and Peterken 1981), a significant advantage is gained by considering only woody plants in the evaluation of woodlands: the ability to carry out evaluations at any time of year, including winter. Some winter evaluations of woodlands did in fact occur during this inventory. Individuals using an evaluation method (city planners, county conservation agents) often need to evaluate the natural quality of a property rather quickly without the luxury of waiting until summer to inspect the herbaceous layer. Woody plants, on the other hand, can be identified in all seasons by trained individuals.

Should a woodland evaluation method that is based solely on the survey of woody plants be considered valid? Intuitively, one would expect to find a diverse flora of woodland herbs in a mature, high quality woodland. On the other hand, a low quality of woodland herbs is anticipated for recently grazed woodlands since this type of disturbance tends to have specific negative effects on the herbaceous layer of a woodland (see above). Clearly, this assumed correlation of woody and herbaceous quality needs to be demonstrated scientifically to further justify the omission of herbaceous evaluation from a woodland evaluation method.

d) Survey intensity. When sampling vegetation in a woodland, a common practice is to establish the number of plots as a function of vegetation variability of an area (Patton 1997). However, sample points were established in proportion to the area of the tract and its topographic diversity during this inventory. Most wooded tracts in the Ames area were surveyed very intensively, with sample points established on every slope, ridgetop and bottomland (e.g., Fig. 2).

Future application of this method may want to consider a vege-

Table 8. "Tree Size" as a potential criterion in future woodland evaluation. The proposed rules for scoring "Tree Size" depend on measurement of the diameter at breast height (dbh) in centimeters of the largest tree in each of the four quadrants of the 0.1 hectare sample plot.

Average dbh of four largest trees in sample plot at least 50 cm	2 points
Average dbh of four largest trees in sample plot at least 30 cm but less than 50 cm	1 point
Average dbh of four largest trees in sample plot less than 30 cm	0 points

tation variance measure as an aid in determining the sample intensity. However, the time and budgetary constraints established for most natural area inventories may preclude this approach.

Other Components

A fifth component, *rare plant species,* was initially considered for inclusion in the evaluation methods for Ames natural areas. For purposes of this inventory, a rare species was defined to be one that occurs on any state or federal list of uncommon (endangered, threatened or special concern) plant species. However, only three species occurring on any of these lists were encountered during field work for this inventory. Thus the occurrence of rare species was considered not effective as an evaluation component and so was dropped from the evaluation method. We feel that occurence of rare species should be recognized independently of the evaluation method presented here, and that any site possessing such species should be designated as a Special Resource (Table 1).

Another commonly used criterion for ecological evaluation, *area of tract,* was likewise not considered beyond the minimum area required to meet natural area designation in evaluation. In Ames, prairie tracts are small and most woodlands occur along rivers and streams, are very attenuated and boundaries are not well defined. In other cities or larger regions, adding points for large tract area might be appropriate.

Natural quality, in part, reflects the maturity of a woodland. One indicator of woodland maturity is the presence of well delimited foliage layers (canopy, understory). Another obvious indicator of maturity is tree girth. The addition of *tree size* as a fifth evaluation criterion could enhance the effectiveness of the method in discriminating among woodlands of otherwise equal quality. With little additional investment of time, the diameter at breast height (dbh) of the largest tree in each quarter of the 0.1 ha sample plot could be measured in the field, then averaged for use in evaluation as outlined in Table 8. Though not used in the Ames study, tree size is included in ongoing studies using a similar method of woodland quality evaluation in northeast Iowa woodlands.

Urban Inventories in the United States

Few American municipalities have undertaken a natural areas inventory as intensive and objective as that described here. Most of the published natural area inventory projects in the United States (Tans 1974, Gelhlbach 1975, Sargent and Brande 1976, White 1978) have had a statewide focus. Some of these are preliminary reports detailing evaluation methodology; often no indication is made that an inventory actually occurred.

A great many natural area inventories have been carried out by university graduate students on a small scale (e.g., county, state park/preserve level). However, the goal of many such endeavors has been the discovery of rare plant species and the generation of a cumulative plant species list for the area of interest, not the evaluation of each existing natural area. Although the value of such information to biologists is undisputed, one questions the usefulness of plant species lists placed in the hands of non-biologists charged with making land-use decisions.

In contrast, the quality rating maps produced through this inventory (Fig. 4) are designed to be used by non-biologists (city planners, private landowners, etc..). The meaning of the quality ratings ("A", "B", "C", and "D") assigned to each delineated quality region are concise and unambiguous (Tables 2 and 5). Specific information about the features of a particular surveyed tract is available in the description, written in layman's terms, that accompanies each map in the inventory document held by the City of Ames (Table 6).

Impact of the Ames Natural Areas Inventory

This inventory has already had a positive impact on Ames natural areas. For instance, survey of the site where federally endangered *Lespedeza leptostachya* occurs revealed that this prairie was being encroached upon by red cedar (*Juniperus virginiana*) trees. Soon afterwards, more than fifty local volunteers gathered to cut down and burn the invading trees during several organized work days in 1993 and 1994. One of the landowners has since put up a sign at the edge of the site that acknowledges this effort by local citizens to restore the prairie.

Likewise, the results of this inventory have been available to a consultant hired by the City of Ames to produce a 30-year zoning and development plan for Ames in anticipation of future growth. In this plan, growth corridors were not proposed for the northwest corner of Ames because of the high quality of the natural resources there (O'Connell pers. comm. 1995).

The final report submitted at the conclusion of a natural area inventory must be taken off the shelf and used by the various city agencies for it to have real impact. This point became clear in the fall of 1995 when a public works crew needed to repair a broken sewer line adjacent to "Ames High School Prairie" (now the Pohl Memorial State Preserve). The works crew was advised by public officials to access the sewer line by crossing the prairie itself to avoid damage to the adjacent woodlands. Consequently, the prairie suffered significant damage when heavy equipment was repeatedly driven across it. If the Ames Natural Areas Inventory report had been consulted, this damage might have been averted. A map of the area (Fig. 6) immediately suggests that the better approach to the work area would have been through "D" quality woodlands, avoiding the "A" quality prairie.

Public awareness of high quality natural areas is no guarantee of their protection. Sometimes the needs of a municipality result in land-use decisions which are detrimental to the health of a natural area. One of the highest quality woodlands in Ames was bisected by a water line installed by a city public works crew in 1994. When the fundamental needs of the public conflict with the maintenance of the highest quality natural areas in a municipality, there are no easy solutions. Nonetheless, the evaluation of natural area quality in a municipality can allow a better assessment of the true costs of alternative land use options.

Future Inventory of Ames Natural Areas

An final inventory report should be viewed as a dynamic document in need of frequent updating. To illustrate, the quality of some of the medium quality prairie remnants identified in the Ames report could improve with appropriate management (i.e., tree cutting, burning). Conversely, the potential decline in quality of prairie remnants should be closely monitored and documented.

Unfortunately, some of the woodlands surveyed during this in-

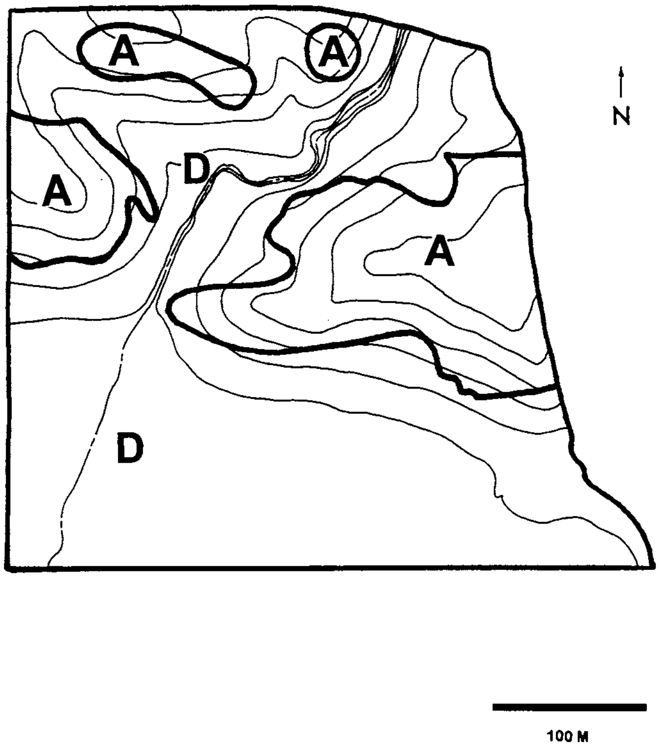

Fig. 6. Topographic map of Pohl Memorial State Preserve (Ames, IA) with woodland and prairie quality regions delineated. A = Highly Natural; D = Highly Altered.

ventory have since been cleared to make way for housing projects. Thus, a resurvey of Ames natural areas ten or twenty years from now is warranted since the current inventory report may by that time be significantly outdated and inaccurate.

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Figure 5 was adapted from figure 4 in Richard Joen's ISU master's thesis (1978)

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