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A METHOD FOR BROAD-SCALE ENVIRONMENTAL EVALUATION AS APPLIED IN AN ENVIRONMENTAL ANALYSIS OF CENTRAL OHIO[1]

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Abstract. A general but comprehensive environmental analysis of the environmental resources of a large region may be conducted utilizing an analysis/index matrix and maps of the analyzed resources. This methodology, previously applied to the 10,976 square mile Central Ohio Water Development Region, incorporates ecologically sound data in a format intelligible to decision makers. Resource maps of the region were completed with features rated, where possible, according to relative significance. Two gridded, summary, composite maps, one for natural components and one for human components, were then compiled. Each grid cell on the natural composite map indexes the significant features in that cell and the land use analog of the ecological seral stage (one of four categories) predominant in that cell. The analog is a comprehensive indicator of the relative degree of natural ecological integrity in the cell. Each grid cell on the human composite map indexes the significant features in that cell and the fair market land value category (one of four categories) predominant in the cell. The land value category is a comprehensive indicator of the human value attributed to that area. The two values for each grid cell on both composite maps are inserted into an analysis/index matrix to yield one of three final analysis/index values. These values, one from a natural perspective and one from a human perspective, indicate areas of overall, relative environmental importance. The natural and the human composite maps may be combined to indicate the areas of potential conflict and tradeoff between these two value systems.

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This paper is a condensed description of the analysis methodology used in the more extensive report, ENVIRONMENTAL ANALYSIS OF CENTRAL OHIO—AN INITIAL APPROXIMATION (Anderson and King 1976). The *Analysis*, as the report will be called in this paper, is an inventory and analysis, based on existing data, of the known environmental resources of the Central Ohio Water Development Region. This region, hereafter called the Central Ohio region, encompasses 10,976 square miles (28,427 sq km) of central and south-central Ohio (fig. 1).

The term environmental, as used throughout this paper and the *Analysis*, refers to all the physical, biological, human and cultural resources of the Central Ohio region. The principal document of the *Analysis* consists of a large map folio containing fifteen 1:500,000 topical component folio maps (plus considerable text and additional smaller scale maps) of these environmental resources compiled by various specialists, and three composite folio maps, plus text, indexing the data on the component folio maps and integrating these data into a final analysis.

The primary purposes of the *Analysis* were to identify those environmental resources which should be included in prudent, long-term, land use planning, and to present this information in a format intelligible and useful to decision makers not necessarily conversant in the sciences. The *Analysis* is general in nature and inappropriate as a basis for formulation of most specific management decisions. It is not an environmental impact state-

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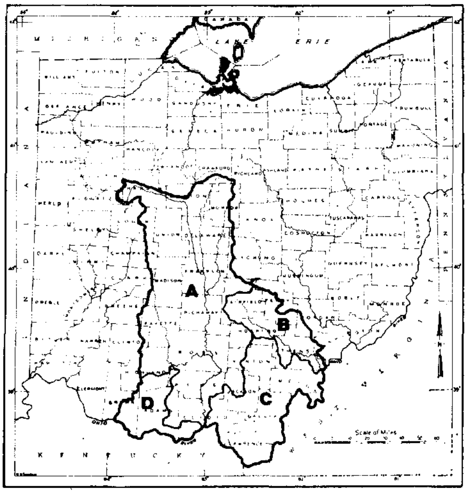

FIGURE 1. Map of Ohio outlining the study area (the Central Ohio region) and constituent watersheds. (A = Scioto River Basin, B = Hocking River Basin, C = Raccoon Creek and Neighboring Basin, D = Ohio Brush Creek and Neighboring Basin).

ment, having many data gaps for areas or elements which had not been adequately field surveyed at the time the *Analysis* was compiled. It is intended to serve as a background source from which more detailed studies may proceed.

Prudent land use planning for long-term benefits requires utilization of basic ecological concepts to weigh accurately real tradeoff values between proposed projects and existing environmental resources. In an effort to assist planners and decision makers in this process, a procedure has been devised to locate known individual environmental features and known areas of high environmental value (*red flag* areas) within the Central Ohio region. This procedure is an attempt to produce a relatively uncomplicated, yet comprehensive, environmental analysis that is based on established and generally accepted ecological and economic concepts. Existing environmental assessment methodologies (e.g., those revised by Warner and Preston in 1974) were deemed inappropriate for the particular types of information assembled and evaluated in this study.

In spite of the imprecisions of the science of ecology, certain generalized basic principles and concepts describing ecological phenomena have been elucidated and accepted as valid by most ecologists. Several of these principles are associated with the development of ecological systems and are relevant to understanding the basic relationships between man and nature and to the determination of environmental values. These principles have significant implications to land use decision-making processes in the Central Ohio region and have provided the ecological basis for the following.

ANALYSIS/INDEX

ENVIRONMENTAL EVALUATION DICHOTOMY

Basic Ecological Principle No. 1: NATURAL PROCESSES OPERATING IN NATURAL ECOLOGICAL SYSTEMS AND COMMUNITIES TEND TO MAXIMIZE DEVELOPMENT OF MECHANISMS AND CHARACTERISTICS WHICH PROVIDE THE CONSTITUENT SPECIES WITH MAXIMUM PROTECTION OR SURVIVAL ADVANTAGES.

Although species in natural systems tend to develop maximum protective or survival characteristics, man in his manipulated ecological systems and communities tends to maximize development of mechanisms and characteristics which provide for *maximum production* or *highest possible yields* from selected species. Frequently, the natural and man-directed processes are in direct conflict. Thus, efforts by society to evaluate environmental resources often result in considerable controversy arising from this inherent conflict, due to widely differing value systems. Although such controversies may never be eliminated or completely resolved, "recognition of the ecological basis for this conflict between man and nature is a first step in establishing rational land use policies" (Odum 1971).

Both natural and manipulated ecological systems and communities *are* of significant benefit to man's survival. The man-manipulated systems, communities, and supporting resources usually provide the most direct short-term benefits to man and generally are evaluated by our society as the more important. The natural ecological systems and communities, however, hold the keys to long-term benefits to man. Most of our society does not perceive this concept, therefore usually evaluates natural communities as irrelevant or contrary to their life support requirements. Recognition of the positive values of both types of ecological systems and communities is a necessary ingredient of a credible environmental analysis.

Certain environmental components relate primarily to the natural aspects of the environment, while others relate more directly to the human supportive and cultural aspects. In an effort to minimize the effects of conflicts of values on the environmental evaluation process, an *Analysis/Index* was developed in which the environmental components investigated in this study were divided into two groups based primarily on the intrinsic characteristics of each component: NATURAL COMPONENTS and HUMAN SUPPORTIVE AND CULTURAL COMPONENTS, as shown in table 1. Natural components were evaluated primarily on their scientific, educational, and intrinsic natural values. Human supportive and cultural components were evaluated primarily on their productivity (or potential productivity) of substances and opportunities suitable for past, present, and future human use.

TABLE 1

Dichotomy of the environmental components in the Environmental Analysis of Central Ohio: An Initial Approximation *as to either Natural Components or Human Supportive and Cultural Components.*

Natural Components	Human Supportive and Cultural Components
Climate	Ground Water
Surface Water	Mineral Resources
Bedrock Geology	Soil Resources**
Physiography	Archaeological Features
Soil Resources*	Historical Features
Vegetation	Cultural Features
Terrestrial Vertebrates	Population Geography
Aquatic Zoology	Population Geography (Amenability to Displacement)
	Landscape Analysis
	Land Use

*Scientific characteristics of soil resources.
**Productivity characteristics of soil resources.

INDEX

One of the primary objectives of the study was to identify and assign significance ratings to the known individual environmental *features* in the Central Ohio region. Certain of these features (including events) on the various component folios maps in the *Analysis* were assigned significance ratings (national/-international, statewide/regional, local, or degraded) by various sets of criteria, a specific set having been developed for each component folio map.

All features receiving ratings on the component folio maps were remapped on either the natural components composite analysis/index folio map or on the human supportive and cultural components composite analysis/index folio map, according to which map they were assigned as indicated in table 1. Each feature was remapped with a symbol denoting the component folio map on which it was originally mapped, thus indicating what general category of feature was present while imparting an indexing quality to the composite folio maps. Additionally, the significance rating of each feature, as originally assigned on its component folio map, was included on the composite folio maps for use in the analysis procedure described below. The composite folio maps were constructed around a Universal Transverse Mercator grid cell system (5x5 km) indicating how many features of each significance level occurred in each cell. Constraints imposed by imprecision of existing data and availability of finances precluded use of smaller grid cells.

ANALYSIS

Another major objective of the study was to evaluate systematically all areas of the Central Ohio region, including those without any known individual component features, from a more comprehensive and environmentally integrated perspective. The objective was to identify the known areas of high general environmental value, or *red flag* areas, in the Central Ohio region.

This environmental evaluation process combined two independent variables by use of a simple matrix to derive analysis/-index values for both the natural components and the human supportive and cultural components for each 5x5 km grid cell (fig. 2). The variables were: INDIVIDUAL FEATURE RATINGS, including significance ratings for natural components features and for human supportive and cultural components features (vertical scale of the matrix) as described above, and GENERAL ENVIRONMENTAL SYSTEM RATINGS, a measure of the known overall environmental worth of the natural components or of the human supportive and cultural components in the grid cell (horizontal scale of the matrix). The objective and comprehensive indicator of the general environmental system rating determined most appropriate for the natural components was the process of ecological succession as represented in the matrix by four land use analogs of ecological terrestrial seral stages (fig. 3). The objective and comprehensive indicator of environmental worth determined most appropriate for the human and cultural components is the real property value in terms of price per acre as represented in the matrix by four fair market land value categories. Both indicators are described in detail below.

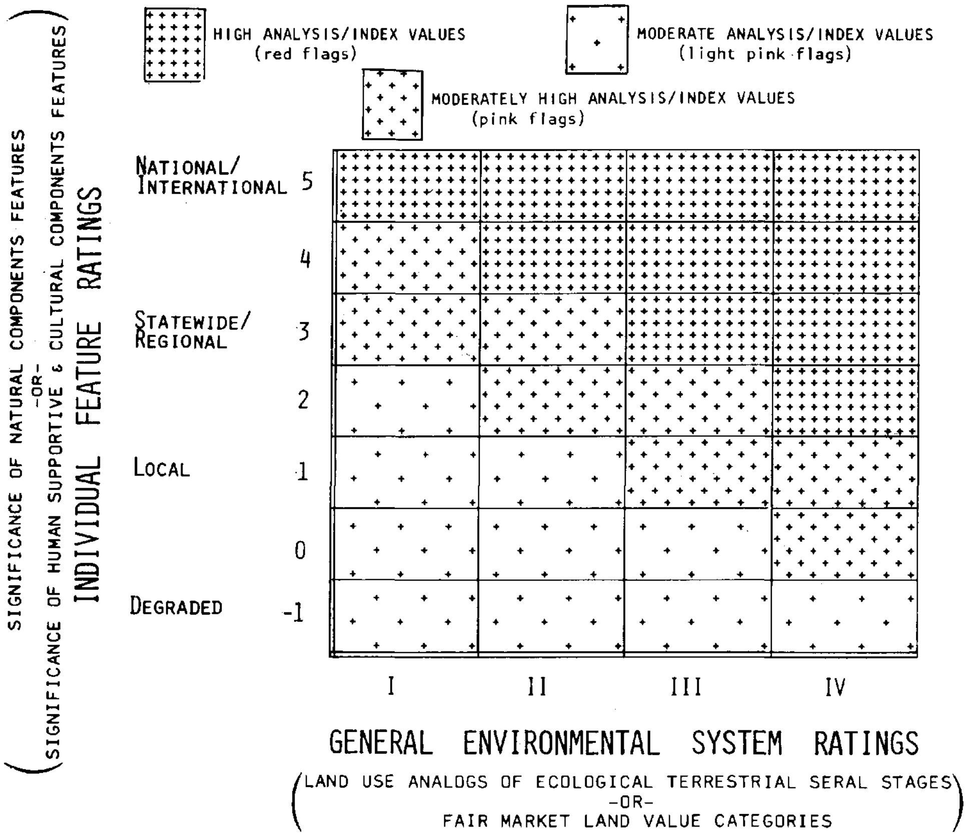

FIGURE 2. Analysis/Index Matrix from which the Analysis/Index Values for the Natural Components and for the Human Supportive and Cultural Components were determined for each 5x5 km UTM grid cell in the Central Ohio region.

The two values for the INDIVIDUAL FEATURE RATINGS variable in each grid cell are determined by the highest significance rating of any feature in the grid cell for natural components features and human supportive and cultural components features. The two values for the GENERAL ENVIRONMENTAL SYSTEMS RATINGS variable in each grid cell were determined by the cell's predominant, by coverage, land use analog and fair market land value.

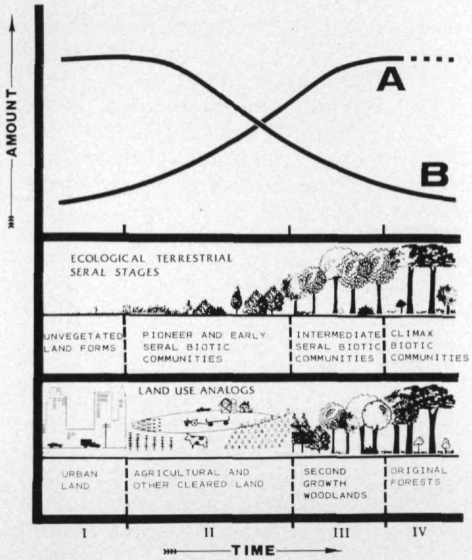

FIGURE 3. Generalized ecological terrestrial seral stages and current land use analogs in the Central Ohio region with reference to generalized relationships of community species diversity (A), community stability (A), and energy subsidy for community maintenance (B).

Finally, the two ANALYSIS/INDEX ratings were determined for each cell. The natural components analysis/index value of a cell is indicated by the rectangle in the matrix which represents the intersection of its INDIVIDUAL FEATURE RATING for natural components and its GENERAL ENVIRONMENTAL SYSTEM RATING for land use analogs. The human supportive and cultural components analysis/index value of a cell is indicated by the rectangle in the matrix which represents the intersection of its INDIVIDUAL FEATURE RATING for human supportive and cultural components and its GENERAL ENVIRONMENTAL SYSTEM RATING for fair market land values.

In the matrix, both the natural components analysis/index values and the human supportive and cultural components analysis/index values were ranked into three categories (high, moderately high, and moderate). Grid cells with high analysis/index values were designated as *red flag areas*. These possess highly valuable, known environmental characteristics. *Pink flag areas* are grid cells with moderately high analysis/index values. They also possess valuable, known environmental characteristics, but not of the calibre of the red flag areas, at least in view of existing information and evaluations. *Light pink flag areas* had only moderate analysis/index values, a reflection of the less valuable known environmental characteristics of those areas. In no instance should the pink and light pink designations be interpreted as analogous to *green lights*. These designations indicate only lower degrees of known environmental values, not absence of environmental values. Further investigations in these areas may reveal environmentally valuable characteristics currently unreported.

In the map folio of the *Analysis* (Anderson and King 1976), the analysis/index values of all 5x5 km grid cells in the Central Ohio region are displayed on three maps: Natural Components Composite Analysis/Index Folio Map, Human Supportive and Cultural Components Composite Analysis/Index Folio Map, and Natural and Human Supportive and Cultural Components Composite Folio Map Indicating Conflicts and Tradeoffs. Each grid cell on the first two maps was given a color (in addition to symbols denoting the individual component features it contains) representing its analysis/index value for that map. The colors provide easy recognition of the relative environmental values of different areas in the Central Ohio region. Each grid cell on the third, combination map was given two colors (separated by a diagonal line) which indicate areas of relative potential conflict and tradeoff between natural and human/cultural interests.

GENERAL ENVIRONMENTAL SYSTEM RATINGS RATIONALE: NATURAL COMPONENTS

In an effort to determine the general environmental system rating for the natural components of a grid cell, a technique based on fundamental ecological relationships was devised using the process of ecological succession as an objective and comprehensive indicator of the degree of integration of the natural components within an area. When a biological area is left undisturbed, a generally orderly process and predictable sequence of temporary biotic communities develop. Ultimately, barring a change in climate, there will form a relatively permanent community (in terms of human civilization time). This process is called ecological succession, with the ultimate stage termed the climax community, the prevailing climax (Whittaker 1953), or the climax mosaic (Horn 1975).

The climax community is complex, dynamic, and self-perpetuating. It is generally characterized by high species diversity, by persistence of certain species assemblages and high community stability (Margalef 1968, Odum 1969). Such a community has developed by evolutionary (at least on a species level) and successional processes over considerable periods of time and is uniquely adapted to the diverse environmental characteristics of the area. Ordinarily, a climax community exhibits the most complete utilization of available environmental resources (Fosberg 1967). A climax community is, in a very real sense, both an accurate and a natural "computer printout" resulting from all the complex interacting (both competitive and synergistic) physical, chemical, and biological inputs into the area. It is the most comprehensive integrated expression available of the natural components for an area. As such, it represents the most significant, integrated, and comprehensive baseline model available for ecological analyses and evaluations of the conditions of other extant biotic communities in an area.

The degree of integration of the natural components into the community increases as ecological succession progresses. A determination of the ecological stage of development, therefore, can provide a direct indication of the degree of comprehensive integration of the natural components into an area. This indication can be translated into a measure of the area's environmental worth or general environmental system rating. To assist this procedure, a generalized ecological terrestrial sere typical of the Central Ohio region is presented diagrammatically in figure 3. This sere was arbitrarily divided into the following four simplified representative seral stages which are readily recognizable by direct observation in the field:

I. **Unvegetated land forms.**
II. **Pioneer and early seral biotic communities:** dominated by annual, biennial, and/or herbaceous and shrubby perennial vegetation.
III. **Intermediate seral biotic communities:** dominated by trees 40–200 years old.
IV. **Climax biotic communities:** dominated by trees over 200 years old.

These four successional stages represent, with a certain degree of accuracy, four ecological systems (ecosystems). Fairly accurate predictions regarding unmeasured ecosystem parameters are now possible from a limited set of available data regarding the general properties of ecosystems (Reichle 1975). For example, Odum (1969) stated that, "the process of ecological succession demonstrates at least 24 ecosystem attributes which show contrasting trends between the early developing seral communities and the mature climax community." Although the applicability of these attributes to ecosystems analysis has been questioned (e.g., Drury and Nisbet 1971, 1973; Horn 1974), modifications and refinements will surely lead to a more accurate understanding of the seemingly orderly successional processes which persistently lead to relatively predictable climax communities throughout the Central Ohio region. Such attributes relating to species diversity, stability, and energy interactions have been selected for expanded consideration regarding land use decision making.

Basic Ecological Principle No. 2: COMMUNITY SPECIES DIVERSITY IS LOW IN EARLY SERAL BIOTIC COMMUNITIES, AND IT IS HIGH IN CLIMAX BIOTIC COMMUNITIES. (See fig. 3, line A.)

Some studies (e.g., Odum 1969) indicated that species diversity generally increased during succession, whereas others indicated that species diversity may be relatively independent of successional stages (e.g., Drury and Nisbet 1973). Horn's (1974) hypothesis is that the highest diversity should occur midway through secondary succession, when there is a maximum combination of both early and late successional species. Such high diversity could be maintained in a dynamic climax situation where a constant cyclic replacement between early and late successional stages occurs within a single system (Forcier 1975).

Despite the conflicts between these theories, most secondary successional stages of *natural* systems in the Central Ohio region display markedly greater species diversities than the early successional, highly-manicured urban and agricultural systems of man. High species diversity is considered a positive environmental value in this study since such diversity, with each species having a "unique survival *strategy*," is necessary to sustain an integrated, relatively closed (at least concerning short-term soil erosion) dynamic climax system over the diverse and dynamic landscape of the Central Ohio region. Of additional value is man's potential direct benefit from this genetic diversity in the form of yet unknown food, fiber, medicinal, basic scientific, educational, and aesthetic resources.

Basic Ecological Principle No. 3: COMMUNITY STABILITY IS LOW IN EARLY SERAL BIOTIC COMMUNITIES, AND IT IS HIGH IN CLIMAX BIOTIC COMMUNITIES. (See fig. 3, line A.)

The definition and understanding of the different concepts of community stability are still being clarified. There are several types of stability concepts, some of which may have inverse or other non-direct relationships during community succession (Horn 1974). In this study, community stability was considered to be the persistence of certain species assemblages through time. In the Central Ohio region the natural communities with the greatest stability are broadleaf deciduous forests. In 1800 A.D. over 95% of the region was covered with such forests (Gordon 1966, 1969) and today abandoned fields persistently return to such forests.

To some degree community species diversity and community stability, as defined in this study, tend to follow similar patterns of development. Recent work by Drury and Nisbet (1973) indicated that there are frequent exceptions to this tendency and that a one-to-one relationship cannot be inferred. Nevertheless, the low natural (i.e., unsubsidized with fossil or other man-manipulated energy sources) community stability associated with the low species diversity of most of man's systems stands in stark contrast to the comparatively high natural community stability and species diversity of most natural dynamic climax systems. High community stability was considered a positive environmental value in this study because it indicated those communities with the highest degree of integration and equilibration, albeit dynamic in time and variable in space, with the substrate and climate of the Central Ohio region.

Basic Ecological Principle No. 4: A CLIMAX COMMUNITY IS IN DYNAMIC EQUILIBRIUM WITH THE NATURAL ENERGY BUDGET OF THE AREA.

Climax communities, characterized as possessing low entropy (Fosberg 1967, Odum 1971), require no additional energy beyond the natural energy budget to continue functioning as relatively stable entities (i.e., entities with persistent species combinations over long periods of time). Such systems work and have worked in the Central Ohio region for thousands of years (Humke *et al* 1975). Any attempt to hold community development at a preclimax stage requires an energy subsidy for maintenance costs. The further the stage is retrogressed from climax, the higher the energy subsidy requirement. This concept is in reality a corollary of Basic Ecological Principle No. 4, and can be stated as follows:

Basic Ecological Principle No. 5: THE AMOUNT OF ENERGY SUBSIDY FOR COMMUNITY MAINTENANCE REQUIRED TO RETARD NATURAL TERRESTRIAL SUCCESSION PROCESSES DECREASES AS MATURITY OF THE BIOTIC COMMUNITY INCREASES. (See fig. 3, line B.)

Extant examples of original or climax

forest communities in the Central Ohio region are limited to only a few small remnants. Thus, virtually all the existing landscape in the study area consists of man-impacted, pre-climax, ecological terrestrial seral stages. Comprehensive data regarding the extant occurrence of these pre-climax seral stages *per se* are not available for the Central Ohio region. Land use areal data for three extant land use patterns which are analogous in certain aspects to the three pre-climax ecological terrestrial seral stages, were available (and presented on the Land Use Folio Map in the *Analysis*). These patterns, presented diagrammatically in figure 3, are:

I. **Urban land.**
II. **Agricultural** and other cleared land.
III. **Woodland** (second growth woodland).

These land use patterns are loosely analogous ecologically to the terrestrial seral stages in at least three ecosystem attributes: community species diversity, community stability, and energy subsidy for community maintenance. Accordingly, these patterns were used as substitutes for measuring the environmental worth (i.e., general environmental system ratings) of different systems (5x5 km grid cells) of the Central Ohio region.

GENERAL ENVIRONMENTAL SYSTEM RATINGS RATIONALE: HUMAN SUPPORTIVE AND CULTURAL COMPONENTS

In an effort to determine the general environmental system rating for the human supportive and natural components of a grid cell, a technique based on current economic relationships was devised using real property value (or fair market land value in terms of price per acre) as an objective and comprehensive indicator of the evaluation by existing society of the human supportive and cultural components in an area.

Fair market land values, or real property values, are a comprehensive evaluation by society of an area in terms of its productivity (or potential productivity) of substances and opportunities suitable for past, present, and future human use. These values are generally determined by processes and reasons completely independent of those which determine environmental values associated with the natural components and have historically been a major factor in the planning process.

One of the primary flaws of any economic value determination by extant society is that future values are rarely considered. Determination of fair market land values is certainly not an exception to this generality, as the real estate market ruthlessly discounts the future. As pointed out by Georgescu-Roegen, prices are only a parochial expression of value unless everyone concerned can bid —and future generations are excluded from today's market (Wade 1975).

In spite of these limitations, fair market land values do, nevertheless, represent a relatively accurate and useful measure of the current society's evaluation of the human supportive and cultural resources of an area. Generalized areal data regarding the fair market land values per acre in the Central Ohio region for March 1973 have been developed (Anderson and King 1976, Chapter 18). These values were divided into four arbitrarily determined categories and utilized in the analysis/index matrix described above.

CONCLUSION

The *Environmental Analysis of Central Ohio—An Initial Approximation* is an inventory and analysis, based on existing data, of the physical, biological, and human supportive and cultural resources of the Central Ohio region. The *Analysis* assumed a basic conflict between the systems of natural communities, whose constituent species maximize survival advantages, and the systems of man, who maximizes production. The *Analysis* attempted to evaluate the resources of the Central Ohio region from both perspectives. It did not, however, attempt to resolve the issues of controversy. It indicated where current and future conflicts are most likely to occur. Upon identification of the factors responsible for each designation, certain conflicts may be resolved, and ecological and economic tradeoffs may be more accurately assessed.

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