Toward A Sub-Model for Ecosystem Stability in the Natural Resource Planning Program

TOWARD A SUB-MODEL FOR ECOSYSTEM STABILITY IN THE NATURAL RESOURCE PLANNING PROGRAM

A TERMINAL PROJECT PRESENTED
BY
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Special thanks for support and direction are due to my committee members: Julius Fabos, Carl Carlozzi and Benjamin Isgur.

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INTRODUCTION

It is the contention of the Natural Resource Planning Program (NRPP) (USDA: Soil Conservation Service, 1974) that it is possible to develop a methodology, both theoretically and practically sound, to assess what constitutes a high quality natural resource environment in a community. The NRPP contains a landscape assessment model which uses a numerical rating scale to express the various levels of a community's environmental qualities and quantities. This scale relates to standards generally recognized as influential or critical to a community's residents. The standards fall under four areas of concern (called parameters); health, ecosystem stability, opportunities for outdoor recreation and aesthetics. From the numerical scoring of the natural resources it is possible for local decision-makers to identify natural resource surpluses and deficiencies as well as to establish priorities for corrective or preventive land use and land management changes.

OBJECTIVES

The objective of this study is to re-evaluate some of the factors which constitute the numerical rating scale in the NRPP model. Specifically, this study will re-examine the standards associated with one of the four main parameters;

namely, ecosystem stability. According to the NRPP assessment model certain land uses or natural resource practices contribute in varying degree to the maintenance of stability in the landscape. A sub-model with a numerical scale expresses the contribution potential, in relative terms, of these land uses to a condition of ecosystem stability. The task of re-evaluating the parameter of ecosystem stability involves 1) establishing a theoretical framework to define ecosystem stability and 2) the construction of a sub-model to demonstrate how resource utilization and land treatment methods may effect the natural equilibrium of the ecosystem.

OPERATIONAL DEFINITIONS

As a model the NRPP is intended to represent a subset of reality. The reality symbolized here is the intereaction of natural processes and human cultural practices and their product - the land uses that exist in the landscape around us. In a model no attempt is made to replicate every process of intereaction; rather key variables and actions are selected for use in the model which are believed to capture the essence of what actually occurs in the reality. A sub-model merely focuses on one aspect or component of the reality.

A parameter, such as ecosystem stability, is a quantity or constant whose value varies with the circumstances of its

application. What interactions constitute a condition of stability will change when natural and cultural factors are significantly altered. (i.e. varying geographic regions or radically differing cultures.)

In the context of this study, ecosystem stability refers to an "ideal" state of the human/cultural environment where the biotic community exhibits a strong ability to self-regulate, regenerate or to experience major perturbations without incurring significant destruction. In the measurement of stability there are levels of concern; 1) the stability of the overall geographic and ecological region and 2) the stability of smaller landscape units which are encompassed within the broader geographic region. This study attempts to measure the relative stability of small individual landscape unit (i.e. land uses) in the belief that the sum of the data of the component parts will reflect the condition or state of overall regional stability.

BACKGROUND

Land use planning occurs within the context of a natural environmental system. Until quite recently, most decisions for urban location, form, and growth were based on economic, social and political factors which, in fact, establish many physical limitations for land use. Negligence in considering these conditions often leads to a desecration of the physical

environment and/or the eventual degradation of the man-made form by the physical factors and processes. An understanding of the natural environment or the natural resource base, its processes, and its ability to accept human creations would therefore appear to be a mandatory first step for a durable human environment.

The natural environment is most accurately understood when viewed as a process. It proceeds through time. The natural landscapes today are products of natural processes that have occurred in direct relation to climatic, hydrologic, physiographic and pedologic phenomena. The interaction of these phenomena tends to establish a balance between land, water and atmospheric elements. A state of balance implies that the numbers and positions of plants, and the numbers and area of occupation of animals, birds and insects, remains fairly constant provided the habitat conditions, such as soil and climate, do not change. But stability does not imply a static state, for in stability renewal of organisms is continuous and evolutionary. As the environmental conditions change, and they do, a new state of balance is achieved. Thus, change in itself is not instability. In fact, as time progresses a more stable natural ecosystem tends to develop.

Natural resource conditions serve to define the size and

diversity of a biotic population that might live harmoniously in the environment. As animals, humans would normally exist in harmony with the environment, but our unique mental capacities have allowed us the power to significantly change the environment and, possibly, its stability. We have our desires to alter our surroundings so they better serve our needs, but at the same time we also endeavor to maintain the natural resources which replenish and satisfy our needs. To resolve this dilemma, humankind must seek to utilize the natural resources base in a manner which contributes least to environmental deterioration or instability.

Human modification of the natural landscape need not result in ecologically instable units. Careful planning can respect and obey the natural patterns and processes. For larger projects of human intervention stability can be achieved by a dominant and stable framework, capable to accepting instability within, but contained by, the framework. It is necessary for humans to alter the balance of nature somewhat, and thus the word "balance" means a dynamic balance.

Because of the inherent complexities of both the ecosystem and the human behavior, this task of establishing a stable framework is extremely difficult. Landscape architects,

ecologist and natural scientists in recent years have proposed various methods of analyzing the natural resources and evaluating their properties to determine limitations and capabilities for land uses (notably McHarg, 1969; and Hills, 1961). These methods call for the comprehension of each resource property and their interrelationships with each other. Maps recording these values are prepared. They are then analyzed according to a list of criteria specifying the degree of limitation each presents for various land uses.

Interest in the larger issue of prevention or elimination of damage to the ecosystem, and even the biosphere, has been stimulated by the National Environmental Policy Act of 1969, which among other requirements, calls for a detailed statement on "...the relationship between local short-term use of man's environment and the maintenance and enhancement of long-term productivity" on major federally sponsored proposed actions (United States 91st Congress, 1969: Section 102, C, IV). A current problem facing environmental planners, however, is the lack of information on which to base decisions concerning environmental effects. Because ecological processes are highly complex, an enormous amount of information is needed. Several, notable Issard (1968, 1972) and Lyle and von Wodtke (1974) have made efforts to collect and organize

this information for usefulness in land use planning. In spite of such efforts, the solution to the problem of lack of useful data remains.

The central question raised by the increased consciousness of ecology is how and to what degree can we exploit our natural resources without causing an overall deterioration/destruction of the environment on which we have so much dependancey. In short, what human resource allocation patterns constitutes a condition of ecosystem stability?

PROBLEM

> There is almost no data based on hard research as to what makes up a high quality natural resource environment. Yet we cannot wait for new research to add to our knowledge about the physical and biological natural resources of our environment before we start to plan the total environment. Society must act to solve present demanding environmental problems. We must use the best knowledge we have and design research to refine our present knowledge. (Isgur, 1972:1)

In response to this challenge, the Massachusetts staff of the USDA Soil Conservation Service developed a planning methodology for assisting communities in formulating a natural resource plan of the renewable natural resource base (USDA:Soil Conservation Service, 1974). The model, entitled the Natural Resource Planning Program (NRPP) attempts to relate natural resource potential to the needs of the land and the people who live within the area of these resources. The program's assumptions are that the natural resource base has

a finite ability to support a certain volume of human population, and that depending on the quantity of these resources (or their ready availability from outside the area) only a specific size population can be supported before the people start to strain the physical environment, causing environmental deterioration.

Structure of NRPP Model

The NRPP is organized into four phases (see Figure 1). The program relies heavily on local citizen participation, thus Phase I involves the organization and mobilization of townspeople who will carry out the program. First a Town Advisory Group (TAG) is organized for the purpose of overseeing the town's NRPP and making important policy decisions during later phases. The TAG has a main leadership role and membership usually consists of representatives of the Board of Selectman, Conservation Commission, Planning Board, Finance Commission, etc.. Secondly, interested townspeople are recruited to serve on subcommittees which will do in-depth inventories of the town's natural resource base.

In Phase II the subcommittees inventory and assess land and water resources following the various categories and criteria established by the Soil Conservation Service. The resources inventories during this phase include: Agricultural

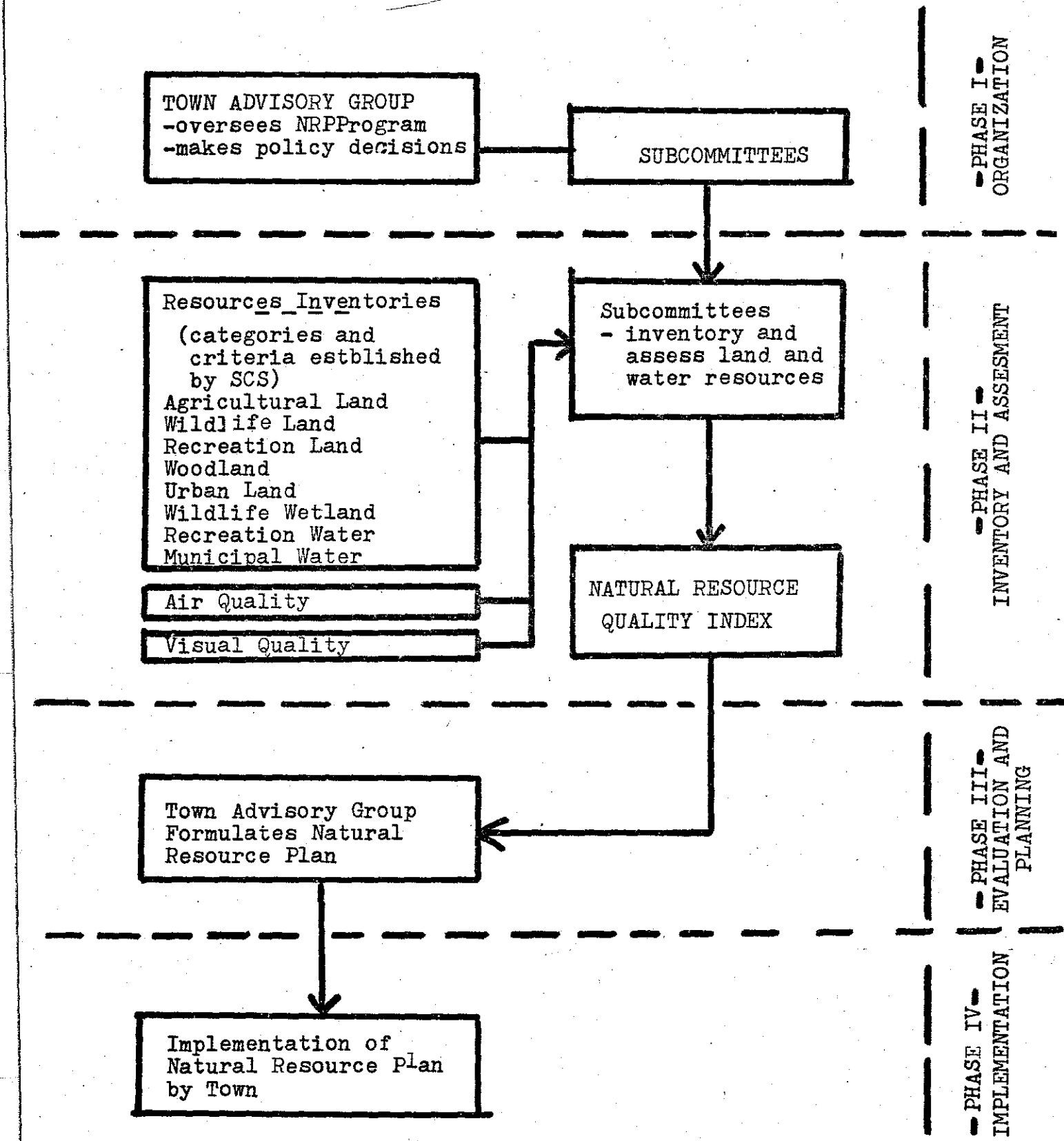


Figure 1: OVERVIEW OF NATURAL RESOURCE PLANNING PROGRAM

Land, Wildlife Land, Recreation Land, Woodland, Urban Land, Wildlife Wetland, Recreation Water, Municipal Water, Air Quality and Aesthetics (visual quality). Data gathered from these inventories are used in a numerical rating scale to express the various levels of community environmental quality and quantity. A single composite score for all the various inventories, called a Natural Resource Quality Index, is calculated providing a measure of the overall condition of the natural resources in the town.

The third phase -- Evaluation and Planning -- consists of a critical evaluation of the natural resource data and the weighing of alternative courses of action reflecting town goals. This evaluation and the formulation of a Natural Resource Plan is carried out by the Town Advisory Group with input from other economic, social and political interests in the community. The idea here is that the town's new plans will improve or upgrade the overall quality of the renewable natural resource base so as to raise the numerical score in the Natural Resource Quality Index.

Phase IV -- Implementation -- occurs as the Town Advisory Group mobilizes a concerted and cooperative effort throughout the community to carry forth its natural resource plans.

Natural Resource Quality Index

This study will focus on Phase II -- Inventory and Assess-

ment -- because it contains the methodology for landscape assessment. Central to this methodology is the Natural Resource Quality Index (NRQI). A closer examination of the Index and how it is derived will reveal weaknesses which this study attempts to correct.

Through the assessment procedure in Phase II it is possible to give each community an index score on a scale of 0 to 100. This Natural Resource Quality Index places a numerical value on the "state" or overall condition of the natural resources in the community. The Index is expected to decrease or increase from year to year depending on how well the community protects or conserves its natural resource base.

The construction of the Index is preceeded by two important steps. First, the communities land uses in eight major categories are inventoried and rated against established criteria to identify their respective and individual values. The eight land and water use categories are; Agricultural Land, Wildlife Land, Recreation Land, Woodland, Urban Land, Wildlife Wetland, Recreation Water, and Municipal Water. The eight categories contain some sixty different land use types. (See Appendix A for the description and definition of these NRPP land use types.) The assessment procedure for each of these inventoried land uses involves the evaluation of each against criteria for four major concerns; quantity, quality, distribution, and modifiers (those factors which modify the

environment in a positive or negative way, such as appearance, condition or multipilicity of use). (See Figure 2). Each land use category obtains a composite numerical value on a scale of 0 to 100. For example, Recreation Land may score 55 points; Wildlife Wetland, 81; and Woodland, 72.

The Natural Resource Quality Index is <u>not</u> just the average of these eight different scores. Rather the relative weight of each land use score is determined in a Step 2. This involves assessing the value each land use contributes to the quality of our environment. Their contribution to the overall condition of the environment is determined through assessing their effects on the following four parameters: Health, Ecosystem Stability, Opportunity of Outdoor Recreation, and Aesthetics. Each of these parameters have sub-parameters, which are as follows:

<u>Health</u>
a. Basic Needs
    1.) Air
    2.) Shelter
    3.) Food
    4.) Water
b. Microclimate
    1.) Temperature
c. Physical Fitness
d. Mental Well-Being

<u>Ecosystem Stability</u>
a. Maintenance Requirements

<u>Opportunities for Outdoor Recreation</u>
a. Capacity for use
b. Intensity of use
c. Diversity of uses

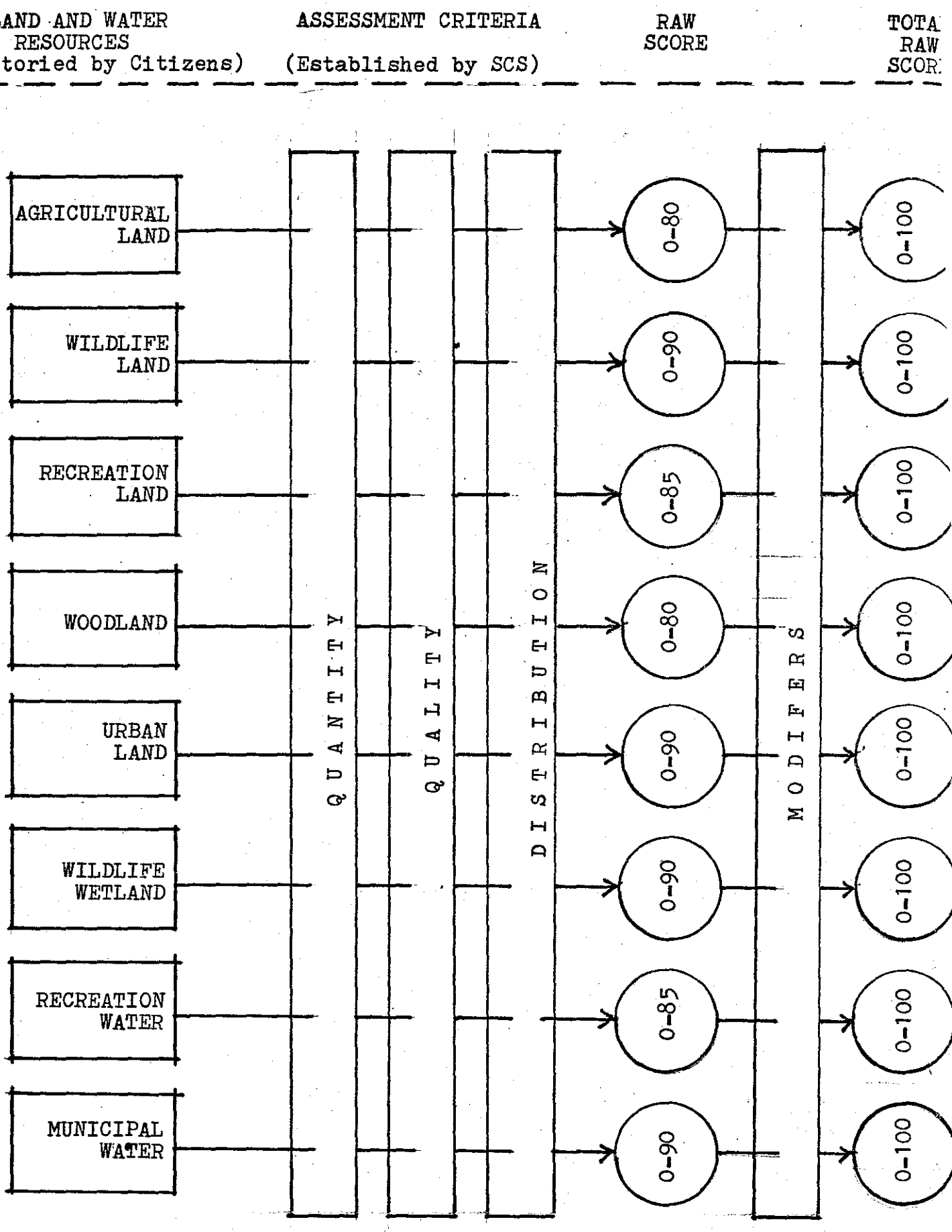


Figure 2: INVENTORY AND ASSESMENT PROCESS FOR

Aesthetics
a. Visual Quality
b. Modifiers

Thus each resource (land use) is evaluated against its ability to satisfy the objectives of the four parameters; namely:

1. Providing a healthful and enjoyable place to live, work and play;
2. Providing a relatively stable ecosystem;
3. Providing adequate opportunities for outdoor recreation;
4. Satisfying a person's aesthetic senses.

The parameter "health" assesses the potential contribution resources make to our physical and mental well-being and comfort.

The parameter "ecosystem stability" evaluates the contribution made by resources toward maintaining a natural equalibrium among and within ecosystems. The sub-parameter "maintenance requirement" measures, in relative magnitudes, the input or effort in terms of cost, resource treatment or management required to maintain a stable ecosystem.

The third parameter, "opportunities for outdoor recreation" assesses the potential of each resource to meet the needs for recreational activities.

The last parameter, "aesthetics" measures the preceived visual quality of the natural resources. (For a more detailed discussion of these parameters, see Appendix K, USDA: Soil Conservation Service, 1974; and Cooper, 1974:6).

Each parameter and its sub-parameter (except Aesthetics) is assigned a numerical value under each land use category (see Table 1). The higher the number, the more important is the contribution of the specific land use believed to be, on that particular sub-parameter. For example, Agricultural Land contributes more to satisfying our need for food than any other land use category.

The numbers in Table 1 were assigned on the basis of professional judgement by an Ad Hoc Committee of the Massachusetts staff of the USDA Soil Conservation Service and many participants from other State and Federal agencies. The only documentation of their decisions is found in Appendix K of the NRPP handbook and the significant portions are extracted and placed below.

> It was assumed by the committee that developed this table that the four parameter....are those that are most significant to man.
>
> The values assigned to each of the parameters were based on judgment and experience, taking into consideration the following factors:
>
> 1. The importance of both the parameters and sub-parameters to man.
> 2. The size of the are involved (in acres).
> 3. The numbers of people involved.
>
> The committee initially established a numerical value, subjectively, to indicate the relative importance of the four parameters one to another... The committee was of the opinion that Health and Ecosystem Stability were the two most important parameters against which to rate resources; that these two parameters were of equal importance; and that together they should

Table 1: PARAMETER RATING TABLE
Source: USDA: Soil Conservation Service, 1974: Appendix K

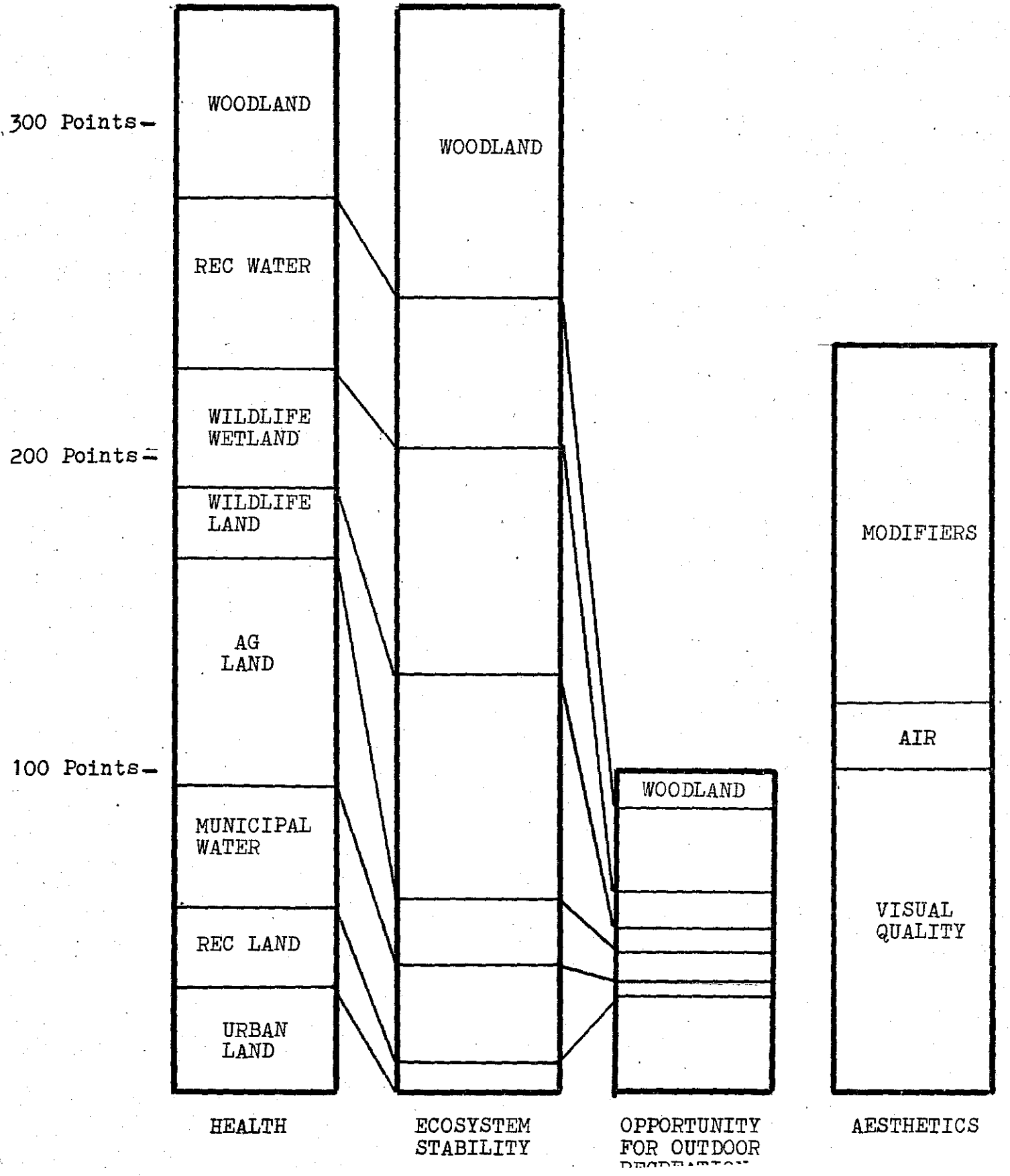
Parameter / Resources	AGRICULTURAL LAND	MUNICIPAL WATER	RECREATION LAND	RECREATION WATER	URBAN LAND	WILDLIFE WETLAND	WILDLIFE LAND	WOODLAND	TOTAL
I. HEALTH									
a. Basic Needs									
1.) Air	5	15	5	15	-	10	5	20	75
2.) Shelter	7	-	-	-	26	-	-	7	40
3.) Food	40	-	-	-	-	-	-	-	40
4.) Water	6	18	6	18	-	18	6	18	90
b. Microclimate									
1.) Temperature	2	4	-	5	5	2	2	10	30
c. Physical Fitness	2	-	10	10	-	2	3	3	30
d. Mental Well-Being	5	-	5	5	-	5	5	5	30
SUBTOTAL	67	37	26	53	31	37	21	63	335
II. ECOSYSTEM STABILITY									
a. Maintenance Requirements	20	30	10	45	-	70	70	90	335
III. OPPORTUNITIES FOR OUTDOOR RECREATION									
a. Capacity for Use	5	2	15	15	-	3	3	7	50
b. Intensity of Use	3	1	8	9	-	4	2	3	30
c. Diversity of Uses	2	1	8	4	-	2	1	2	20
SUBTOTAL	10	4	31	28	-	9	6	12	100
TOTAL (Item I, II, III)	97	71	67	126	31	116	97	165	770
IV. AESTHETICS									230
TOTAL (Item I, II, III, IV)									1000

> On the basis of the latter assumption and with the total maximum parameters' value established as 1000. Health was assigned 335 points and Ecosystem Stability was assigned 335 points. The remaining 1/3 of the total value of 1000 or about 330 points was assigned nearly equally to Opportunities for Outdoor Recreation (100 points) the visual quality component of Aesthetics (100 points), and the modifier component of Aesthetics (130 points).
>
> Essentially the same approach was used in establishing a total value for each sub-parameter.....
> ..... The final step in establishing rating values for the contribution of each resource to the sub-parameters and, in total, to the parameters consisted of:
>
> 1. Asking the question, "What is the relative contribution of each resource to the sub-parameter under consideration?"
> 2. Establishing a ratio of the relative contribution each resource makes and,
> 3. Dividing the total available points established for each sub-parameter..... and distributing them among the resources in accordance with the established ratio or resource contribution.....
>
> (USDA: Soil Conservation Service, 1974:Appendix K)

Figure 3 gives a graphic summary of the Rating Table (Table 1) and reveals how one resource may be valuable in satisfying one parameter, but less so in another.

The Totals under each resource (land use) on the Rating Table reflects the relative weight each contributes to the overall condition of the environment. They are as follows:

Figure 3: GRAPHIC SUMMARY OF PARAMETER RATING TABLE

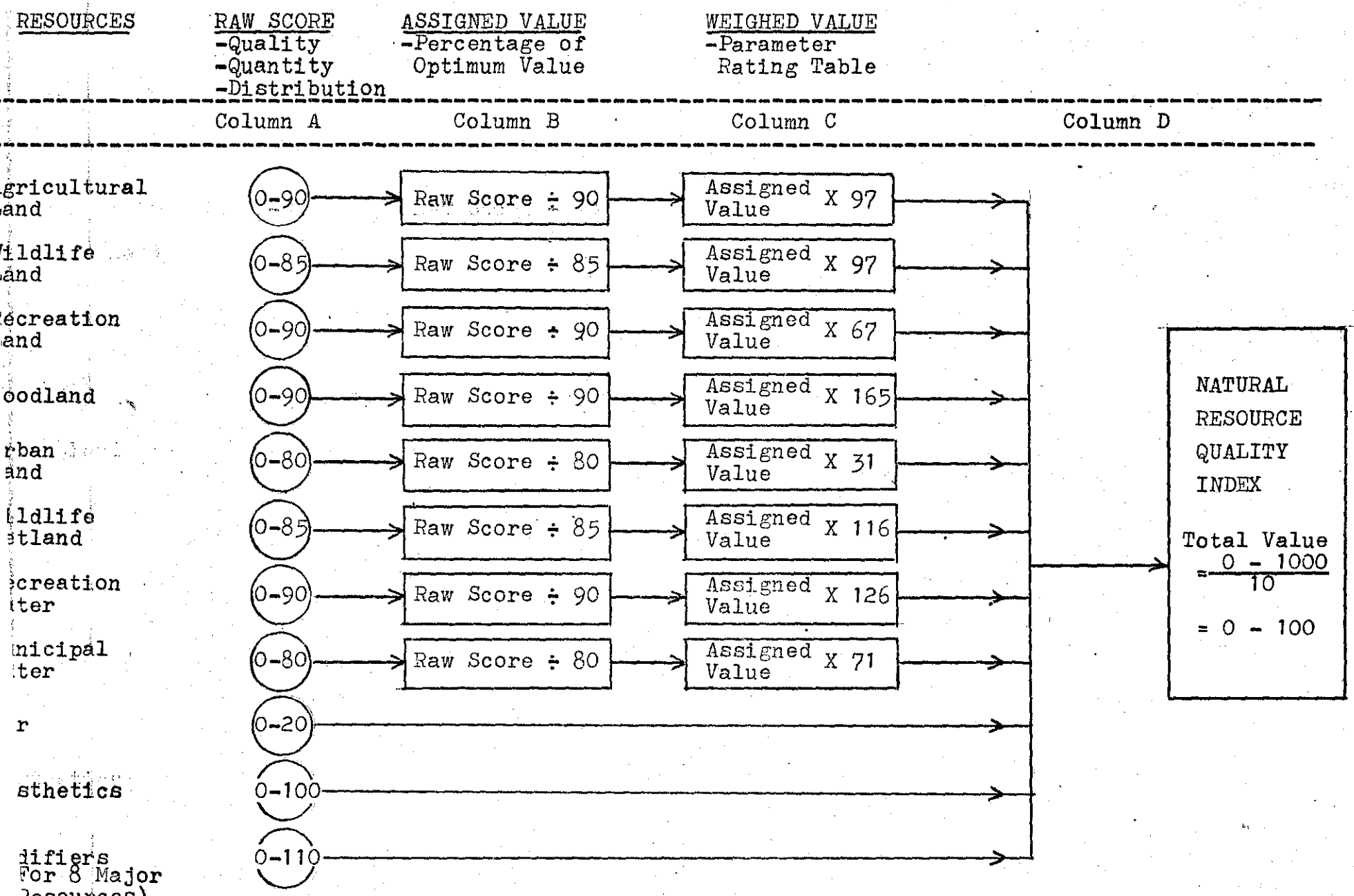


Resources	Points
Woodland	165
Recreation Water	126
Wildlife Wetland	116
Agricultural Land	97
Wildlife Land	97
Municipal Water	71
Recreation Land	67
Urban Land	31
	770 Total Points

Thus it is judged that Woodland has the highest potential to contribute the most to the quality of our environment; Urban Land the least.

The total points assigned each resource in the Rating Table becomes a weighed value for computing the NRQ Index. (see Figure 4, column C.) The NRQ Index for a given community is computed, as illustrated in Figure 4, in the following manner. Start with the raw score (column A) for each inventoried resource in Figure 2, page 13. This raw score is the sum value each resource received against its respective criteria for quantity, quality and distribution. The values received for the modifiers of the first eight resources are totaled and recorded on line 11. For the eight resources, the raw scores are converted to a percentage (of optinum values) figure, called the assigned values in column B. These assigned values are then multiplied by the weighed values, obtained in Table 1, for their respective resources. The eight resultant products are summed and added to the raw

Figure 4: **SUB-MODEL FOR COMPUTING NRQ INDEX**



scores received in the inventories for Air (line 9), Aesthetics (line 10) and Modifiers (line 11). The grand total will be a number between 0 and 1000 (column D). For easier comprehension, this number is arbitrarily divided by 10. The quotient then has a value between 0 and 100, and this number is the community's Natural Resource Quality Index.

The effectiveness of any assessment model is related to its accuracy. Thus the closer the NRQ Index simulates the actual conditions of the environmental processes occurring among the community's natural resource base, the more validity and utility the Index will have as a planning tool. To strengthen its validity it is first necessary to document the principles upon which the Index is based. This documentation, for the most part, appears to be missing. This problem is particularly acute for the parameter "ecosystem stability".

Hence, the object of this study from here on is the parameter "ecosystem stability", its sub-parameter(s) and the designated values of each land use to the sub-parameter(s).

The parameter of ecosystem stability relates the attributes of land and water uses as they contribute toward a natural equilibria within the ecosystem. As noted, it contains only one sub-parameter - maintenance requirements.

Each land use is assigned a value which weighs the relative magnitude of input or effort in terms of cost, resource treatment or management required to maintain a stable environment. These values are summarized below.

Resources	Values
Woodland	90
Wildlife Wetland	70
Wildlife Land	70
Recreation Water	45
Municipal Water	30
Agricultural Land	20
Recreation Land	10
Urban Land	0
	335 Total

From the above table, the cost of maintaining Woodland as a land use is one-ninth as great as the cost of maintaining Recreation Land; one-half as great for Recreation Water; etc. The assignment of these values was not documented by the original Ad Hoc Committee with research, nor described by rationale. These values, we can only assume were derived from the member's best professional judgement. If the actual costs were researched and set to scale, the validity and sensitivity of the Index would no doubt be improved.

But a more serious flaw may be the choice of maintenance requirement as the sole sub-parameter to assess ecosystem stability. Does the cost required to maintain a land use accurately simulate the contribution a land use makes

to enhancing the stability of the natural processes? Again, there exists no documentation or rationale in the NRPP literature to support the choice "maintenance requirement"; nor, in fact, is there any indication that any other sub-parameter(s) was even considered.

In summary, this study will conduct a re-evaluation of the principles relating to ecosystem stability as used in the Natural Resource Quality Index.

LIMITATIONS

This study of ecosystem stability is designed for implementation in the Natural Resource Planning Program. As such the geographic region of interest is limited to Land Resource Area #144 - New England and Eastern New York Upland Area (Austin, 1965). Only resource categories and ecosystems typical of this area will be evaluated.

Secondly, because this study is in the context of the NRPP assessment methodology the investigation here is restricted to internal considerations of the individual contributions of each land use to the condition of ecosystem stability. The parallel construction of land use/resource assessment in the NRPP model dictates that individual resources be separately analyzed. This is particularly unfortunate, for ecosystem stability is a dynamic process where its' component parts (the individual ecosystems) in-

terrelate. Land use patterns, distributions and concerted actions, no doubt, contribute a great deal to the overall stability of the ecosystem. The ecological compatibility of land uses is the object of another study (Hendrix, 1974) and beyond the structure of this study.

A third limitation also derives from the restrictive structure of the NRPP model. An assessment methodology for the Parameter Rating Table must be non-site specific. A parameter by its definition is a value constant for a land use category in the model's geographic region. The assessment of the stability of individual and specific land uses occurs in the inventory and assessment procedure (step 1 in the construction of the NRQ Index), not in the Parameter Rating Table. This limitation means that the assessment variables must be kept very general in nature.

Fourthly, this study focuses on only a small issue in the NRPP model. If this study succeeds in improving the sensitivity of a segment of the NRQ Index, it does not necessarily follow that the sensitivity of the Index itself is enhanced. This may not occur until all the component assessment procedures that compute the Index are re-evaluated.

Finally, the development of a hypothesis on the contributions land uses to the condition of ecosystem stability will evolve largely from concepts and theories developed by

Eugene P. Odum, and Alumni Foundation Professor of Zoology at the University of Georgia, Athens, Georgia.

PROCEDURES

In re-evaluating the contribution potential of land uses to the parameter ecosystem stability, this study will attempt to: 1) add sub-parameters to the ecosystem stability parameter in the Natural Resource Parameter Rating Table, 2) refine the importance values assigned there to the various land use classifications, and 3) write a clear and objective rationale for the above with supportive references and bibliography.

Chapter II establishes the theoretical dimensions for defining relative stability among land uses. The chapter is divided into two parts. Part I examines pertinent ecological concepts and theories relating to stability development in the natural environment. It discusses how the structure and function of ecosystems, operating over time, serve to create a broad stable framework capable of containing human landscape modifications. This part of the chapter concludes with a discussion of key variables for measuring natural stability.

Part II in Chapter II explores the influences human have on changing the natural environment and establishes a conceptual framework for defining stability on a cultural/

natural notions of stability and presents three distinct approaches which will serve as new variables (or sub-parameters) in assessing ecosystem stability.

Chapter III organizes these variable into a sub-model capable of comprehensively measuring ecosystem stability. Research supporting the establishment of standards for these variable is presented. Finally, the new importance values assigned each sub-parameter are incorporated into the NRPP Parameter Rating Table.

Chapter IV summarizes and evaluates the validity and utility of this study.

C H A P T E R II

CONCEPTS ON STABILITY IN THE NATURAL/CULTURAL ENVIRONMENT

In order to establish a theoretical framework to define ecosystem stability, this chapter will review theories and concepts pertinent to the understanding of how ecosystems behave under the influence of a natural/cultural environment. This chapter is divided into two sections. Part I -- Principles of Ecosystem Stability -- explores ecological concepts that define stability within the context of the natural environment. Part II -- Human Influence on Ecosystem Stability -- reviews the current theories of just how human culture affects the equilibrium of the natural world.

PART I - PRINCIPLES OF ECOSYSTEM STABILITY

Some select principles relating to the structure and function of ecosystems will be presented in this part of Chapter II as background to establishing a theoretical framework for a sub-model assessment of ecosystem stability. These principles are presented in the belief that the values and strategy of ecosystem development are most appropriate for forming an objective value system which assesses the consequences of cultural activities on the quality of natural environment and its self-renewing capabilities. While many of the concepts presented are still theoretical in character, an attempt will be made in Part II of this chapter to show

their practical application.

The concepts presented will illustrate that the current sub-parameter in the NRPP model - maintenance requirements (energy subsides) - is a narrow and insufficient variable for being the sole measurement of ecosystem stability. In describing ecosystems and their development strategy, their succession, cybernetics, bioenergetics and flow of matter and energy through their system will be discussed.

Concept of Ecosystem

The study of the interrelationships between organisms and environment is commonly called ecology. The word environment is vague. The "environment" for a particular organism needs a more operational definition.

Pierre Dansereau (1966), in the Conference on Future Environments of North America, presented a scheme of the biosphere showing the order of magnitude of the environmental relationships. His scheme, in Figure 5, identifies eleven units. They are from smallest to largest; the molecule, organelle, cell, tissue, organ, individual, population, community, ecosystem, cioclimate and biota. Some kind of exchange takes place between each of these units and the next greater one, of which it is a part. For example, the individual is an "environment" for the organ; the population is an "environment" for the individual. Similarly, the ecosystem is

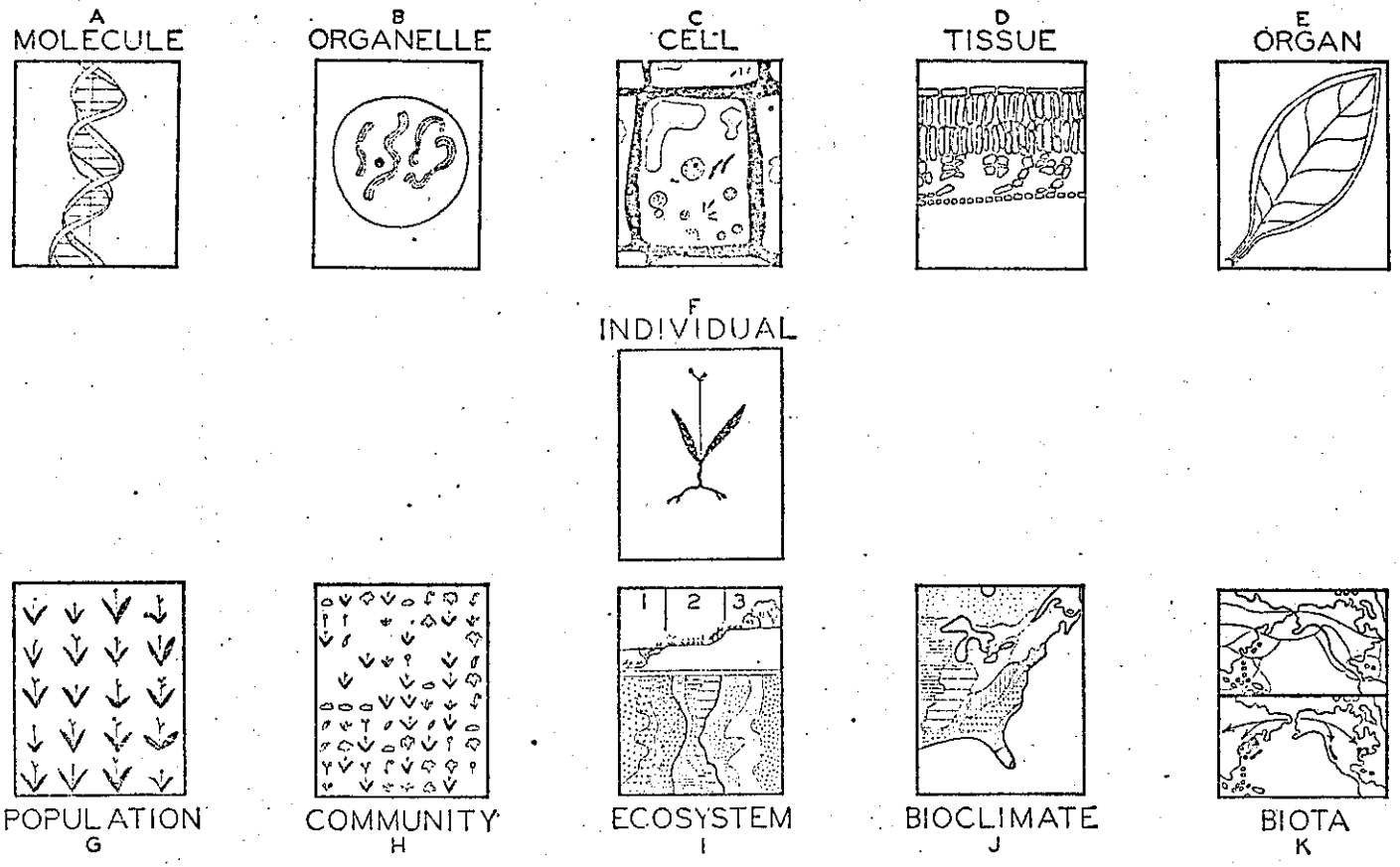


Figure 5: SCHEME OF THE BIOSPHERE: ORDERS OF MAGNITUDE OF ENVIORNMENTAL RELATIONSHIPS
SOURCE:
DANSEREAU (1966:429)

an "environment" for the community. These units are interrelated through a "process" or series of related processes that elicits responses which give form to a number of patterns, definable at each level.

Dansereau suggests that level G through K (particularly the first three; population, community and ecosystem) are the prime object of the study of ecology. The ecological dimensions of life are measured... "by establishing how population is affected by soil, air, water, other plants, and by animals, and how it has fitted itself into one or more communities." (Dansereau, 1966:430).

More specifically, Eugene Odum (1962) prefers to define ecology as: The study of the structure and function of ecosystems.

> By structure we mean: (1) the composition of the biological community including species, numbers, biomass, life history and distribution in space of populations; (2) the quantity and distribution of the abiotic (nonliving) materials such as nutrients, water, etc.; (3) the range, or gradient, of conditions of existence such as temperature, light, etc.....
>
> By function we mean: (1) the rate of biological energy flow through the ecosystem, that is, the rates of production and the rates of respiration of the populations and the community; (2) the rate of material or nutrient cycling, that is, the biochemical cycles; (3) biological or ecological regulation including both regulation of organisms by environment (as for example, in photoperiodism) and regulation of environment by organisms (as, for example, in nitrogen fixation by microorganisms). (Odum, 1962:6).

Ecosystem Succession

Ecosystems are not static. Their structure and function change or evolve over time in the process of ecological succession or ecosystem development.

> (1) It is an orderly process of community development that involves changes in species structure and community processes with time; it is reasonably directional and, therefore, predictable. (2) It results from modification of the physical environment by community; that is, succession is community-controlled even though the physical environment determines the pattern, the rate of change, and often sets limits as to how far development can go. (3) It culminates in a stabilized ecosystem in which maximum biomass (or high information content) and symbiotic function between organisms are maintained per unit of available energy flow. (Odum, 1969:262)

This progressive, terminative and directional change in ecosystems is best illustrated in vegetative community succession. Examples of plant succession in terrestrial and aquatic ecosystems are shown in Figure 6. While the general process of succession is continuous, several distinct types of communities, or seres, may be recognized over time. These are, in order of succession: Pioneer Stage; the first or initial plant community which invades a site void of all vegetation, Intermediate Stages: the development of various herbs grasses, shrubs and trees after the pioneer stage has prepared the site for further invasion; there may be several different intermediate stages, Climax Stage; the final stage of plant succession. The basic difference between terrestrial

Figure 6: EXAMPLES OF ECOSYSTEM SUCCESSION

SUCCESSIONAL STAGES	TYPE OF SUCCESSION	SOIL-MOISTURE CONDITION
	TERRESTRIAL SUCCESSION	
PIONEER STAGE	A. Bare Fields	XEROPHYTIC
	B. Grasses	
	C. Grasses and Shrubs	
	D. Shrubs and Small Trees	
	E. Coniferous	
	F. Coniferous Hardwood Forest	
CLIMAX STAGE	G. Mixed Hardwood Forest	MESOPHYTIC
	AQUATIC SUCCESSION	
PIONEER STAGE	A. Open Inland Water	HYDROPHYTIC
	B. Deep Water Marsh	
	C. Shallow Water Marsh Seasonally Flooded Flats Abandoned Cranberry Bog Meadow	
	D. Shrub Swamp	
	E. Wooded Swamp	
CLIMAX STAGE	F. Forest Cover	MESOPHYTIC

and aquatic succession is that they start from radically different hydrologic states. The terrestrial environment starts from a zeric (dry) condition and aquatic environments from a hydric (wet) condition. They both however, culminate in a mesic (moist) condition.

As soon as one plant community substantially modifies a site, a succession takes place and a new community develops. Thus, each sere prepares the way for a new community, until, in the climax or mature stage, an equilibrium between biotic and abiotic elements is achieved.

Ecosystem Cybernetics

Ecosystems are capable of self-maintenance and self-regulation as are their component populations and organisms (Odum, 1971). That is to say, in order to self-perpetuate itself, an ecosystem is capable of developing, without outside controls, through a self-correcting homeostasis (homeo=same; stasis=standing). Thus, homeostasis allows an ecosystem to survive major internal stresses and changes that might otherwise upset the internal equalibrium.

This control depends on a system of feedbacks, where output feeds back as input. Figure 7 illustrates this control. Positive feedbacks, deviation-accelerating, are those inputs which stimulate accelerated change in the system with potential impact enough to destroy the entire system. These

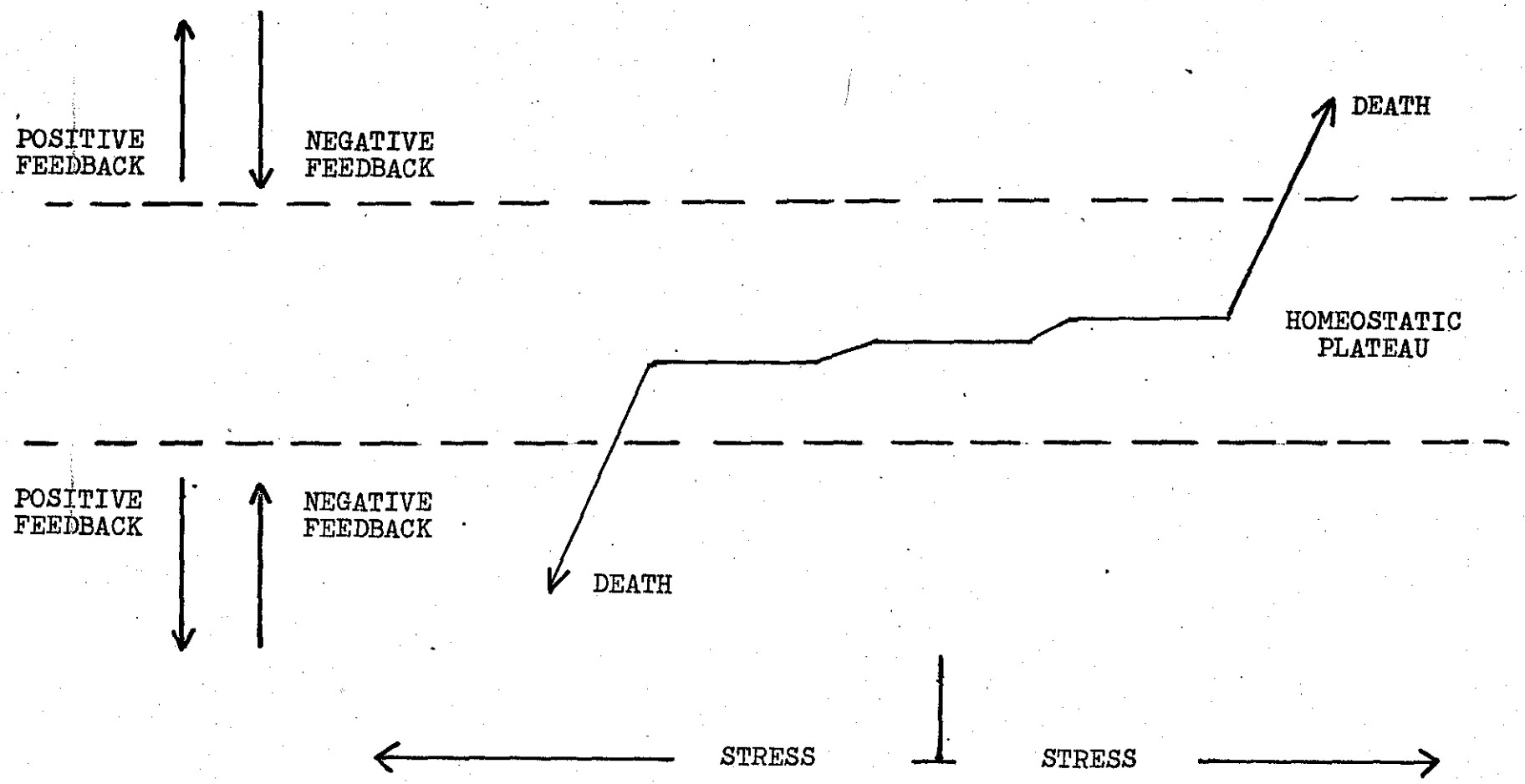


Figure 7: HOMEOSTASIS:
THE TENDENCY FOR BIOLOGICAL SYSTEMS TO RESIST CHANGE AND REMAIN IN A STATE OF EQUILIBRIUM
ADOPTED FROM ODUM, 1971:34

positive feedbacks are countered with negative feedbacks, deviation-counteracting; inputs which serve to check potentially dangerous acceleration. In the absence of negative feedbacks, the system dies. Depending of the strengths of negative feedbacks, the level of resultant equilibrium may vary to establish different steps on the "homeostatic plateau."

As a system evolves through evolutionary adjustment its ability to establish homeostatic control increases.

> New ecosystems (such as a new type of agriculture) or new host-parasite assemblages tend to oscillate more violently and to be less able to resist outside perturbations as compared with mature ecosystems in which the components have had a chance to made mutual adjustments to each other. (Odum, 1971:35)

Ecosystems exhibit three important attributes of cybernetic control: (1) self-creation, (2) self-reparation, and (3) self-adjustment (Zube, after Carlozzi, 1971:13). The capacity of ecosystem to develop new genetic forms and diverse function over long periods of time in response to long term stress is called the self-creative function. The ability of the system to develop successional stages of development, climaxing in mature stable equilibrium, is called the self-reparing function. They systems ability to respond to short term stress is called the self-adjusting function. These three functions are in continuous operation.

Principles of Energy and Matter

Central to the function of the ecosystem is the interaction of energy and matter. Energy, in the form of sunlight or heat, flows one way through all ecosystems. Energy, as the fuel, is "burned", transformed or stored in the ecosystem, before it is eventually dispersed as heat in a degraded condition outside the system (Second Law of Thermodynamics). All life depends on this flow of energy. Matter and materials do not flow into or out from a "closed" ecosystem, but rather are recycled within it. The biosphere of our earth may justly be called the only truly "closed" ecosystem.

Through the process of photosynthesis organisms in an ecosystem store radiant energy in the form of organic sustances which can be used by other organisms as food material. The important stages in this primary production of organic substance (biomass) is illustrated in Figure 8.

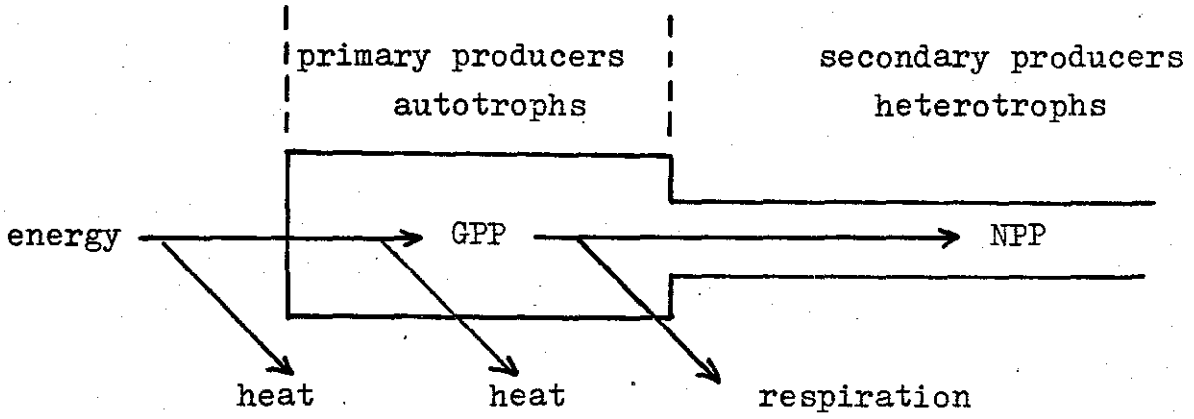


Figure 8: THE TRANSFORMATION OF ENERGY

Only a small percentage (about 40) of light entering an ecosystem is absorbed by the primary producers (mainly green plants) and transformed through photosynthesis and chemosynthesis activity to organic material. The total amount of food initially stored is called the Gross Primary Production (GPP). Part of this production is used by the producer as food to maintain its life functions; in the process, some of the initial energy stored as food is respired and dissapated as heat. The Net Primary Production (NPP) is that which remains "unused" by the producers and is available as food (energy) to organisms on lower trophic levels. The amount of available energy must always decrease with each successive trophic level.

This movement of energy and the rate at which it flows through an ecosystem is important to the concept of stability. Respiration creates a loss of energy; energy given off when

an organism respires is no longer available for utilization. The less energy that is wasted in the system by respiration, the more available that energy is to support larger communities. The flow of energy through a system acts to organize that system.

Respiration is a maintenance cost. In general, the larger the biomass the greater the maintenance cost, "but if the size of the biomass units (individual organisms, for example) is large (such as vegetation in a forest), the antithermal maintenance per unit of biomass structure is decreased" (Odum, 1971:39). Margalef (1963) also found that the more mature ecosystems with a richer structure have a lower primary production per unit of biomass. In the presence of stress the cost of maintenance (respiration) increases. The self-repairing and self-adjusting attributes of the ecosystem work to create a stable state where internal cost of maintenance is constant; where the energy available is efficiently utilized.

High rates of production can occur when physical factors are favorable and when energy subsides (such as tital action or human labor) from outside the system reduces organism respiration. However, prolonged use of energy subsidies tends to make the internal system less self-serving and self-regulating. Removal of subsidies can cause sudden stress and instability, resulting in great loss of production if

not death (Odum, 171:43).

Strategy of Stability

Both the structure and function of ecosystems change within the duration of ecological succession. Odum (1969b) has listed the major changes that occur in the structural and functional characteristics of a developing ecosystem. This list is preproduced in Table 2.

> "The strategy of succession as a short-term process is basically the same as the strategy of long-term evolutionary development of the biosphere -- namely, the increased control or homeostasis with, the physical environment in the sense of achieving maximum protection from its pertubations." (Odum, 1969b:262)

Table 2: A TABULAR MODEL OF ECOLOGICAL SUCCESSION: TRENDS TO BE EXPECTED IN THE DEVELOPMENT OF ECOSYSTEMS*

Ecosystem Attributes	Developmental Stages	Mature Stages
Community energetics		
1. Gross production/community respiration (P/R ratio)	Greater or less than 1	Approaches 1
2. Gross production/standing crop biomass (P/B ratio)	High	Low
3. Biomass supported/unit energy flow (B/E ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detrit
Community structure		
6. Total organic matter	Small	Large
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Species diversity-variety component	Low	High
9. Species diversity-equitability component	Low	High
10. Biochemical diversity	Low	High
11. Stratification and spatial heterogeneity (pattern diversity)	Poorly organized	Well-organized
Life history		
12. Niche specialization	Broad	Narrow
13. Size of organism	Small	Large
14. Life cycles	Short, simple	Long, complex
Nutrient cycling		
15. Mineral cycles	Open	Closed
16. Nutrient exchange rate, between organisms and environment	Rapid	Slow
17. Role of detritus in nutrient regeneration	Unimportant	Important
Selection pressure		
18. Growth form	For rapid growth ("r-selection")	For feedback control ("K-selection")
19. Production	Quantity	Quality

Overall homeostasis

20.	Internal symbiosis	Undeveloped	Developed
21.	Nutrient conservation	Poor	Good
22.	Stability (resistance to external perturbations)	Poor	Good
23.	Entropy	High	Low
24.	Information	Low	High

*From E.P. Odum, in Science, 164:262-270, April 18, 1969.

Table 2 compares the condition of ecosystems at their developmental or young stage with their mature or older stage. Most ecosystems reach (or will reach eventurally) maturity. However, more or less regular but acute physical perturbations from outside the system can "halt" an ecosystem at any intermediate stage in the development sequence.

Every attribute in Table 2 shows a contrast in the ecosystem's characteristics between the youthful and mature stages. Thus, these attributes are recognized as measurable indicators of change.

While all 24 attributes are operationally significant indicators, certain ones are more useful and more important than others. Some of these attributes, such as net community production (#4), food chain (#5), total organic matter (#6), biochemical diversity (#10), nutrient conservation (#21) and entropy (#23), are more difficult to determine than others. (Vilkitis, 1973:17)

> "..(Odum)...places greatest reliance on production/respiration ratios as measurable characteristics that would indicate not only the general trend in succession development but also would allow us to measure the departure from stable, healthy natural community norms." (Carlozzi, 1971:98).

Production/Respiration Index. Attribute #1 in Table 2 on pages 40-41 describes the essential changes that occur

in the bioenergetic functioning of ecosystems during succession. In the developmental stages the rate of primary production or total (gross) photosynthesis (P) exceeds the rate of community respiration (R); resulting in a P/R ratio of greater than 1. As the ecosystem develops to maturity this ratio approaches 1, as the total amount of energy fixed becomes balanced by the total community respiration (or the energy cost of maintenance) in very simple terms; as a ecosystem reaches its metabolic climax it consumes about what it makes. The P/R ratio then is a functional index of the relative maturity of the system.

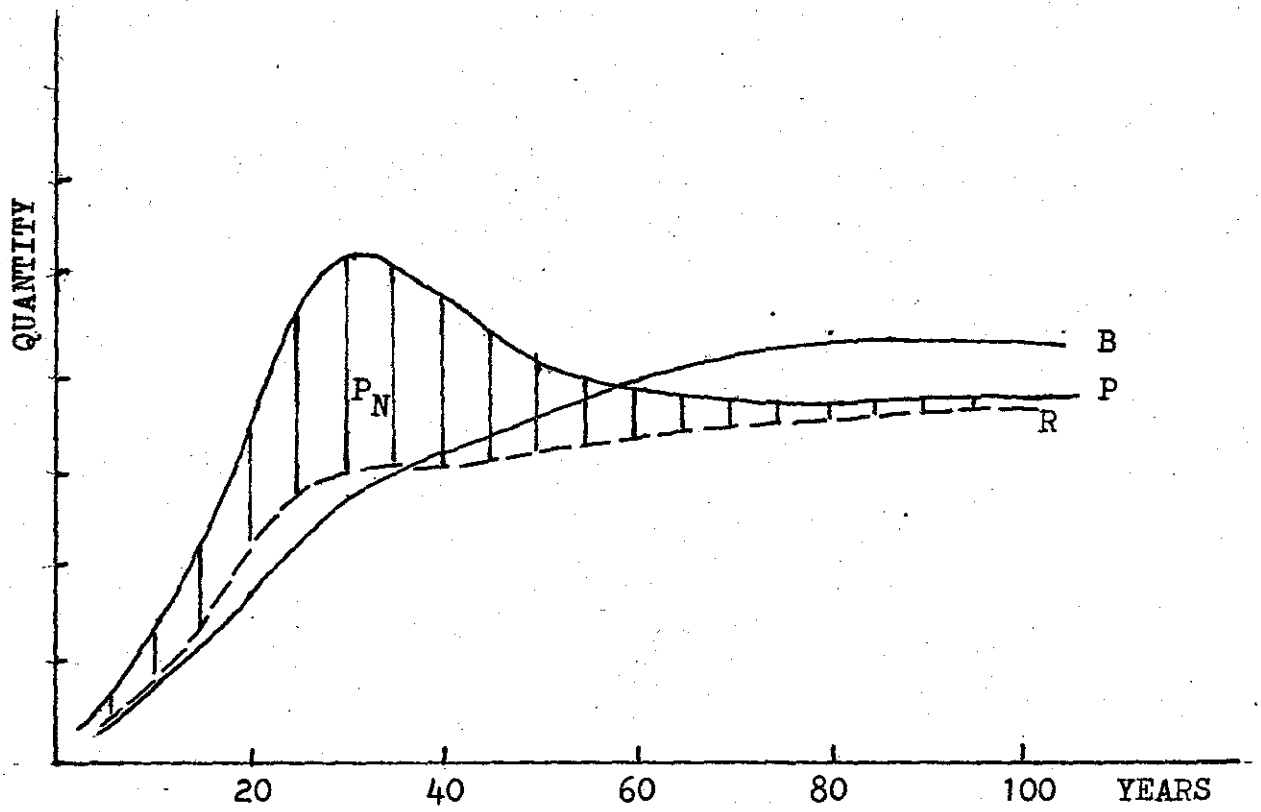
Figure 9, illustrates the metabolic changes of a forest ecosystem studied by Kira and Shidei (1967). In the early stage of development, production (P) exceeds respiration (R), resulting in an accumulation of high biomass (B) and high net production yields (Pn). The production declines as the system matures and levels off at a rate approximately equal to the system's respiration.

It is believed that P is always greater than R in the early stages of autotrophic succession. In heterotrophic succession, however, R is often greater than P in the beginning. In either succession, P approaches R at maturity.

SUMMARY

A selected set of ecological facts and concepts re-

Figure 9: ECOSYSTEM DEVELOPMENT IN A FOREST
Source: Kira and Shidei (1967)



YOUNG:
- o Gross production / Community Respiration $\frac{P}{R} = > 1$
- o Accumulation of organic matter and biomass
- o Net production yield is high

MATURE:
- o Gross production / Community respiration $\frac{P}{R} = 1$
- o Net production yield is low

lating to ecosystem stability in the natural environment has been presented. From this survey the following points form a conceptual framework for understanding ecosystem stability in the natural environment.

1.) Ecosystem stability is definable as the ability of the system to buffer and control the physical and biological factors of the universe. As this ability increases, the stability of the system increases.

2.) Stability is synonymous with ecosystem maturity. Maturity is a measure of self-preservation, internal order and self-control.

3.) Nature strives for maturity; it progresses toward stability.

4.) Ecosystem stability is a relative term. Some ecosystems are more stable than others because of their different degrees of development. The gradients of ecosystem stability are measurable.

While the concept of maintenance requirement (energy subsidy) appears theoretically valid as an indicator of instability, it is somewhat limited in scope. For instance, the concepts fails to illustrate the degree or condition of an ecosystem's maturity. In addition, the amount of subsidy per se does not delineate the kind or quality of

maintenance performed. Some subsidies, particularly those introduced by humans, may serve to reduce biotic diversity, soil fertility, or community structure.

Part II of this chapter will expand upon this latter point by explaining how human intervention in the processes of the natural environment affect the definition of ecosystem stability.

PART II - HUMAN INFLUENCES ON ECOSYSTEM STABILITY

Humans have existed as a dominant force for only the last five or six thousand years in a physical world that has been a habitat for other life for well over 300 million years. During this brief reign humankind has gained increasing control over the natural and physical environment to the extent where our cultural activities may now adversely impact the equilibrium strategy of the natural environment. The interface of cultural activities with the natural environment will be the subject of Part II of this chapter.

Scale of Human Intervention Over Time

According to Pierre Teilhard de Chardin (1956) the appearance of modern man introduced to our planet a new "psychically reflexive human surface"; "a revolution in the very process of evolution;" with the emergance of the noosphere (noos=mind). The noosphere is a world of spirit-in-matter that is not bound by the confines of the biosphere.

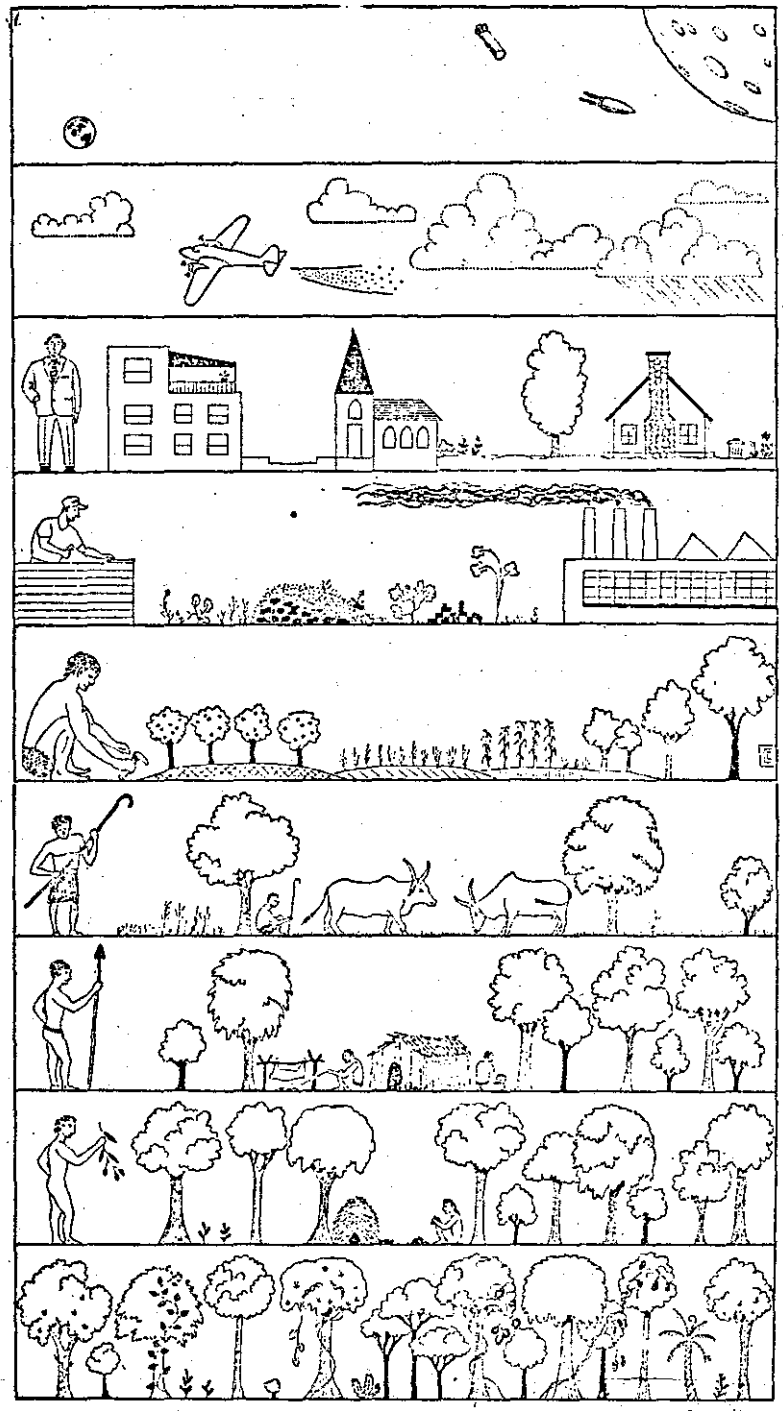
It may, in fact, be called a new ecosystem.

Dansereau picks up on this thought when he describes two principle aspects of human capacity to impact the natural environment: "the upsetting of natural balances by the elaboration of completely new ecosystems on the one hand, and the deliberate molding of evolutionary forces in living organisms (including himself) with the elaboration of new genotypes on the other hand. (Dansereau, 1966:449)"

Dansereau (1957, 1966) traces the gradual evolution of human control in his "scale of human interference in the landscape" (Figure 10). Such human processes as housing construction and food gathering have drastically changed as we have climbed each of the eight rungs on the scale. Each step, or level of social organization, represents a progression and an intensification of human activities within the natural ecosystem. The human role has moved from being subordinate in nature to accomplishing dominance over nature; from a primitive to a complex technical industrial culture.

Human culture has progressed largely through the exploitation of natural resources. Resources are natural elements which at a particular time assume a value in the culture. Different resources have had different uses by varying cultures. Firey (1960) has analyzed the resource practices

Figure 10: SCALE OF HUMAN INTERFERENCE IN THE LANDSCAPE
(Dansereau, 1966:450)



of many cultures and found distinct patterns of resource usage. Firey, for instance, separates resource practices into those "1) resource complexes; resource processes that show constancy and stability in the face of change that is external to itself, and those 2) resource congeries; resource processes that are unstable and vary widely in response to external change." (Firey, 1960:14).

Rodiek (1974) has extracted from Firey (1960) the following attributes of resource practices:

A. Resource complexes vary according to <u>type</u>.
   1. Basic human activities
   2. Human activities assisted by machines that give advantage.
   3. Human activities assisted by technical devices, particularly devices that harness energy by utilizing steam or fossil fuel mechanisms.

B. Resource complexes vary according to <u>complexity</u>.
   1. <u>Simple</u> resource complexes involve few human or biophysical resources.
   2. <u>Complex</u> resources complexes involve many sophisticated human and biophysical resources.

C. Resource complexes vary according to <u>scale</u>.
   1. The resource complex may be large or small in real extent. (Rodiek, 1974:13)

Another prespective on the human interface with the ecological systems is added by Calozzi (1968). The early centers of civilization depended on their immediate geographic regions for raw materials.

> "In ecologist's terms, (their) energy and matter cycles were site-bound; the total system was closed. ....Today our major cities are not site-bound..... the energy powering the works of the city, the raw materials supplying its industries and much of the food feeding its people may orginate from regions far removed." (Carlozzi, 1968:198).

Carlozzi sees our various economic supply-market systems as a continuum progressing through time leading from the closed primitive systems to the open metropolitan-industrial system. Closed systems maintain an equilibrium between population and resources; open systems do not.

Rodiek (1974) has effectively summarized the increasing impact humans have gained over their environment. (see Table 3). Each level of social organization on Rodiek's

Table 3: THE SCALE OF HUMAN INTERFERENCE OVER TIME

Adopted from Rodiek (1974:15)

	CRITERIA	Level of Social Organization					
		Gathering	Hunting Fishing	Herding	Agriculture	Industrial	Urban-ization
DANSEREAU	1. Human Role	Subordinate Primitive	Subordinate-dominat Primitive	Dominant Emerging	Dominant Emerging	Dominant Technical	Dominant Technical
FIREY	2. Resource Practice						
	a. Type	Basic	Basic	Basic	Mech. Tech	Tech	Tech
	b. Com-plexity	Simple	Simple	Simple	Simple-Complex	Complex	Complex
	c. Scope	Small	Small	Small	Small to Large	Large	Large
CARLOZZI	3. Degree Of Openess	Closed	Closed	Closed	Tending to open	Open	Open

matrix is matched with its respective dominant ecological/ cultural characteristic.

The landscape of an urban society is far different from that of a gathering culture. We now construct huge dams, desalt the ocean water, erect complex shelter; all to manipulate the natural environment to suit our needs. The industrial society exploits and interrupts natural processes to the point where we are forced to spend effort even to maintain the very system that once supported us.

Strategy of Humankind

Humans are social organisms and as such their interactions with the biological and physical environment constitues functioning ecosystems. Our awareness of our dependancy on other humans is more obvious than is our awareness of our functional relationships with the natural world. As a result some of our processes and practices obey ecological principles while others do not. It is certain, however, that human ecosystems do not operate under the same tight cybernetics as do natural ecosystems. And without such "laws of science," human ecosystems are less predictable, less directed. This implies that if our actions work counter to nature at one particular point in time, they may not, indeed, need not behave similarly another time. That our survival in the long run depends on a strategy compatible with the natural ecosystems is well established and need not be documented here.

Regardless of the various historical fluxuations in resource values, the dominant strategy of human culture has been the optimization of capturing nature's productivity (Odum, 1969a). From the earliest civilizations on we have learned to tap nature at her most productive stages. We eat her fruits, chop her broadest timbers and cultivate the riches soils. But we have gone further, by purposefully developing and maintaining early successional types of ecosystems, usually monocultures. To feed and support a growing population it has been necessary to "push back" the succession of ecosystems to their most productive stages and to hold them there. Our objective has been to fix the biotic community at some stage below climax. Tansley (1939: 224) first coined this unique landscape modification phenomena "anthropogenic climax." Odum (1971:267) refers to it as "disclimax."

The practice of establishing anthropogenic climaxes and their effects on organic and natural processes is best illustrated in our agricultural practices.

> "Most of man's cultivated plants are light tolerant pioneer species, and even in the derived strains tend to maintain such characteristics. Agronomy tends toward monoculture and the convenience of a single crop on a single site. In the short run this may allow a large production of desirable product, such as corn or cotton. In the long run, however, such monoculture results in soil erosin, loss of fertility, poor utilization of water, and an incomplete utilization of the periodic opportunities for habitat utilization." (Cain, 1968:26).

Obviously, not all our resource practices work against the equilibrium of the natural processes. For aesthetic and recreational reasons we have also practiced conservation principles through the establishment of wilderness areas and parklands. Such areas are allowed to reach their natural climaxes.

Another consequence of our resource practice is the introduction of foreign and particularly dangerous substances into the natural environment. There are many substances, both organic and inorganic, which are interruptive to the biochemical cycles and destructive to biotic organisms. The impact of these pollutants on human health and on the structure and functioning of the ecosystem has been the subject of extensive research in the past decade.

What is needed now is to be able to assess, in relative terms, exactly how our varying resource practices impact the strategy of stability in local natural ecosystems. What kind of landscapes have our strategies created? What are the positions of our anthropogenic climaxes vis-a-vis the natural climaxes; and of what significance is the gap?

Methods of Assessing Ecosystem Stability Along the Cultural/Natural Landscape Continuum

Several methodologies have been developed which deal directly or indirectly with the task of assessing ecosystem stability in the context of the cultural/natural landscape.

Three such models will be presented here. They are chosen because they satisfy a number of objectives. First, all three are quantifiable; they are capable of assessing on a broad numerical scale the magnitude of impact cultural activities have on the condition of stability. Secondly, each addresses itself to a different and distinct aspect of ecosystem stability. They are not duplicative. Finally, each represents an ecological approach in that their criteria is based in scientific fact, setting the stage for objective evaluation.

These three assessment methodologies effectively bring together the cultural/natural notion of stability. They are judged appropriate for serving as new variables (or sub-parameters) for measuring ecosystem stability in the context of the NRPP model. For this reason they are presented only briefly here and will be expanded upon in the next chapter.

Maintenance Requirements - SCS. As the current and sole indicator of ecosystem stability in the Soil Conservation Service's NRPP model, this assessment methodology was discussed earlier (pages 12, 14 and 15). The amount of energy expended by humans to maintain an ecosystem may be viewed as an artifical energy subsidy. Placed in the context of the principles of energy flow through natural ecosystems (see pages 36-38) the maintenance requirement

scale becomes a valid indicator of relative stability for a cultural/natural ecosystem. The sensitivity of the index would be increased, of course, if the actual values on the scale were researched.

Compartmental Model - Odum. Working from the principles of natural ecosystem development, Odum (1969a, 1969b) developed a planning strategy compartmentalizing the landscape into four simplied biotic-functional units. These units are; 1) mature, 2) growth, 3) non-vital, and 4) multiple use. Odum's assessment system recognized land (as represented by its biological communities) to have an overall production value which is a function of its particular structure, size and overall respiration.

Mature systems are protection environments, where succession is allowed to reach its natural climax. They are the stable ecosystems where the general production/respiration ratio is equal to one. The production environment, of growth systems, are those from which biomass harvest is possible. The production/respiration ratio is kept at a value greater than one. Non-vital systems are places of high energy consumption such as urban landscapes. Their P/R ratio is less than one and ecologically they are highly unstable. Compromise environments, or areas of multiple use, are at some point between protection and production; having a P/R ratio of

less than or equal to one.

Odum's compartments are on a successional continuum from non-vital to protection; from unstable to stable systems. It is Odum's contention that the whole landscape must contain each of these four units, and that they must be linked or arranged in certain ways for mutual benefits.

> "Knowing the transfer coefficients that define the flow of energy and the movement of materials and organisms (including man) between compartments, it should be possible to determine through analog-computer manipulation, rational limits for the size and capacity of each compartment..... and by continually refining the transfer coefficients on the basis of real world situations, and by increasing and decreasing the size and capacity of each compartment through computer simulation, it would be possible to determine objectively the limits that must eventually be imposed on each compartment in order to maintain regional and global balances in the exchange of vital energy and of materials." (Odum, 1969b:262)

While our scientific knowledge of these transfer coefficients is still inadequate to permit computer application at this time, the compartmental model does have some immediate utility. For example, we can begin to classify cultural/natural landscapes into their proper compartments and receive a crude reading on their relative positions on the successional or stability continuum. Urban-industrial areas are non-vital; croplands, productive; rivers and lakes, compromise; and watershed forests are protection landscapes.

Hendrix (1973) has proposed that Odum's compromise compartment be expanded to include <u>two</u> compromise areas;

one falling between production and protection landscapes, and the other between production and non-vital landscapes. Like the other compromise area, Hendrix's unit would serve as a buffer; in this case, between production and non-vital areas. This proposal appears valid as it faciliates more clearly the successional continuum without destroying Odum's original linkage flows. Thus the compartmental model may have five units.

Pollution Impact on Ecosystem Health - Metland. Two separate models designed to assess the effects human land use activities have on ecological and biological systems have been developed by the METLAND 9Metropolitan Landscape Planning Model - Fabos, 1973) team at the University of Massachusetts at Amherst. These two model (Careaga, 1973; Fehrer, 1975) measure the pollution generated by various land uses and assess their impact on the air and water quality. Air and water are considered to be important transport mechanisms which carry pollution material from one ecosystem to another. The pollutants analyzed are limited to those either actually human-made, such as inorganic pecticides and plastics, or human-induced, such as runoffs from fertilized fields, fallout from airborne pollution, etc..

The METLAND rating procedures indentifies first the relative impact the key pollutants have on ecological systems (ecosystem health; as opposed to human health) and then corelates the magnitude of impact with the land uses that generate such pollutants. Thus the METLAND submodels, together, provides an estimate of just how much each land use potentially interfers with the biotic processes of ecosystems, upsetting their natural equilibrium.

Summary

The preceeding discussion of human influences on natural ecosystem stability reveals the following points:

1.) Cultural activities tend to interrupt natural processes and destroy natural ecosystem stability.

2.) The strategy of humankind to exploit productivity is in conflict with the natural strategy of obtaining maturity and protection. Cultural landscapes are more unstable than natural landscapes.

3.) Ecosystem stability must be measured along a cultural/natural landscape continuum and there are three assessment procedures available which can accomplish this task. These procedures are capable of measuring the flow of materials (METLAND) and energy (SCS) as well as bioenergetic function

(Odum) of various landscape systems. Together, they provide a broad and comprehensive tool for measuring relative stability among ecosystems. These three procedures will be described in detail in the next chapter, for they form the foundation for a new sub-model for measuring ecosystem stability within the context of the Natural Resource Planning Program.

C H A P T E R I I I

SUB-MODEL FOR MEASURING ECOSYSTEM STABILITY

A new methodology for assessing the parameter ecosystem stability within the context of the Natural Resource Planning Program will be presented in this chapter. The methodology is a sub-model which quantitively assesses the contributions, in relative terms, of various land uses to the condition of ecosystem stability.

The objective of the sub-model will be reviewed first, followed by an overview of the sub-model itself, and then a detailed description of its component parts.

OBJECTIVE OF SUB-MODEL

Certain land uses, expressed along a natural/cultural continuum, are more valuable than others in preserving and sustaining the self-regulating, regenerating and self-protecting characteristics of ecosystems. The objective of this sub-model is to indicate which land uses contribute, in what quantity, to the condition of ecosystem stability. The sub-model is designed as a possible replacement methodology for the parameter ecosystem stability in the current NRPP Parameter Rating Table. It should be recalled that the importance values in the Parameter Rating Table serve as weighed values in the compulation of a community's NR Quality Index.

AN OVERVIEW OF SUB-MODEL

Component Parts

The sub-model for assessing ecosystem stability has three component parts: 1) inputs, 2) variables and 3) outputs. These components have the following procedural flow:

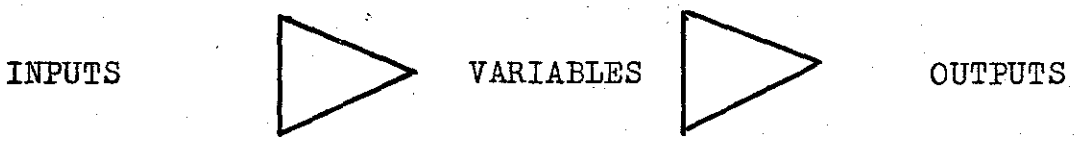


Figure 11: PROCEDURAL RELATIONSHIPS OF SUB-MODEL

Since this sub-model assesses the contributions of each land use to the condition of ecosystem stability, the inputs for the sub-model are land use types. The variables are those key factors which are best capable of describing the condition of ecosystem stability. The variables contain the standards used to evaluate the relative stability among the inputs. The conceptual framework for the variables was established in Chapter II and the three variables themselves were presented in the latter part of Chapter II. The outputs for this sub-model are numerical scores or importance values which can be placed in the NRPP Parameter Rating Table.

General Assessment Procedures

The schematic flow of the sub-model is illustrated in Figure 12, and operates in the following manner. A land use type is inputed into the sub-model and processed through three

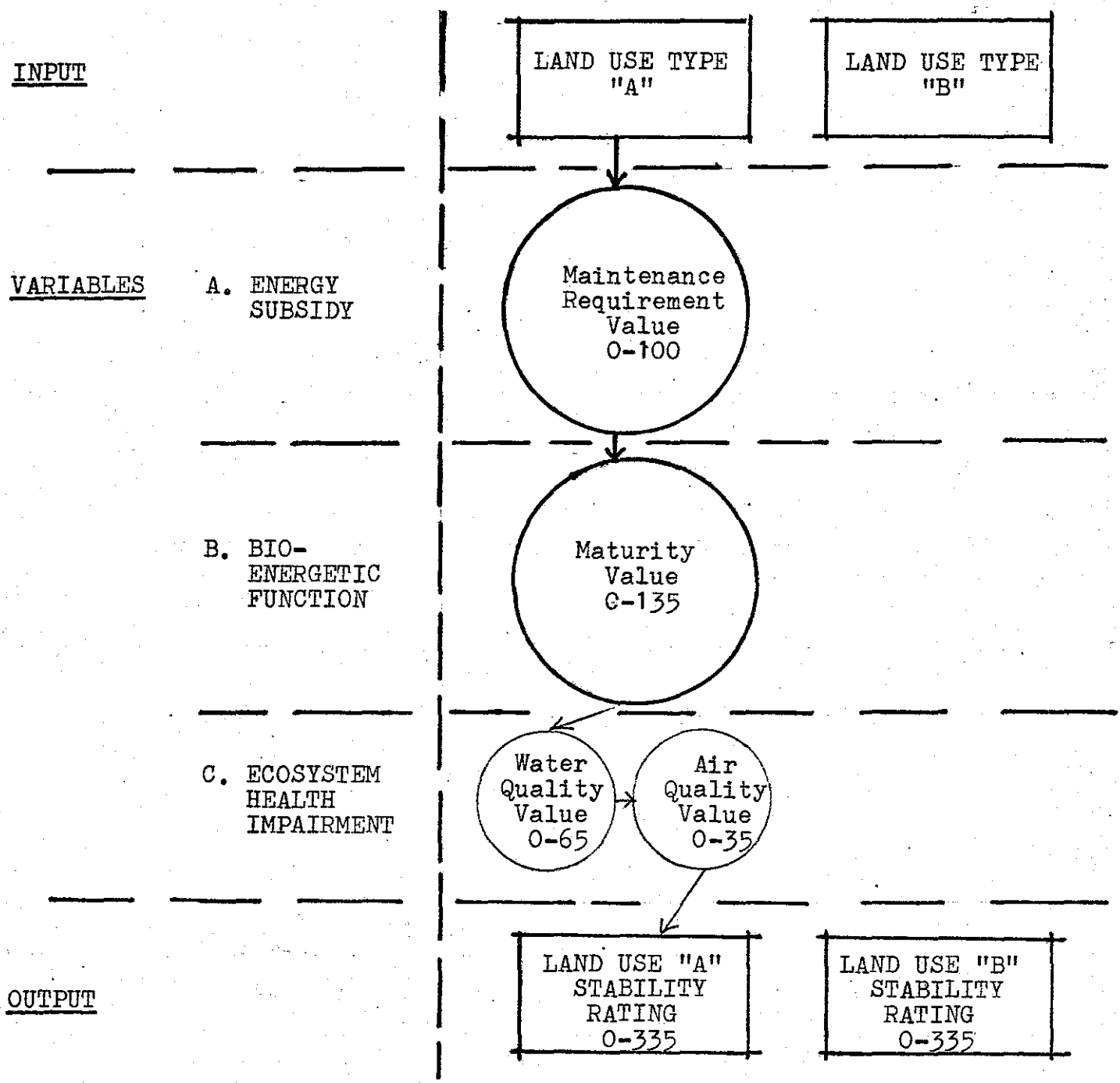


Figure 12: SCHEMATIC FLOW OF SUB-MODEL

different variables (a. energy subsidy, b. bioenergetic function and c. ecosystem health impairment) and their associated scales (maintenance requirement, maturity and water and air quality values). A land use type picks up a numerical value from each scale. The higher the value the greater the contribution that land use has to the condition of ecosystem stability. The values for each land use type on each scale are summed and the total points received represents a stability rating; the sub-model's output. The process is repeated for each input or land use type until each receives a stability rating.

INPUTS

The land use classification system selected for inputs in the sub-model are those conforming to the NRPP model. The eight NRPP land use categories are; Agricultural Land, Wildlife Land, Recreation Land, Woodland, Urban Land, Wildlife Wetland, Recreation Water and Municipal Water. These categories are defined, along with their individual land use types and coding system, in Appendix A.

For the assessment procedures of the variables, it was necessary to have information of the number of acres in each land use in the Resource Region #144 (Austin, 1965). A comprehensive inventory of land use in Resource Region #144

has been conducted, in 1971, by MacConnell and others (1974) and their land use classification system (Massachusetts Map Down) and inventory were used in the submodel for acreage data. (The Massachusetts Map Down land use classification system is described in detail in Appendix B). The Massachusetts Map Down land uses were inventoried by counties and for convenience Franklin, Worcester and Middlesex Counties in Massachusetts were equated with Resource Region #144. In the application of the acreage data to this sub-model every effort was made to correlate accurately the Massachussetts Map Down land use classification system with the NRPP system.

VARIABLES

Introduction

Three variables have been selected in Chapter II for inclusion in this sub-model. The three variables are; a) energy subsidy, b) bioenergetic function and c) ecosystem health impairment. A reasonable amount of research and data collection exists to justify these variables and to establish standards for assessment.

The three variables may be considered as sub-parameters to the parameter ecosystem stability in the NRPP model. The process of natural ecosystem development, as established in Chapter II, is essentially concerned with the flow of matter and energy. Each of the variables enumerates on

these processes. Energy subsidy deals with the human intervention into natural energy flows; ecosystem health impairment focuses on the dntroduction of foreign matter (pollution) into the natural environment; and the bioenergetic function variable measures the human influences on the natural delicate balance established between the flows of energy and matter.

As sub-parameters in the NRPP Parameter Rating Table, certain quantitative values have been assigned to each variable. This sub-model accepts the assignment of 335 points to the parameter ecosystem stability. Thus the 335 points have been distributed among the three variables (sub-parameters). The bioenergetic function variable was viewed as being most comprehensive and therefore assigned the most points, 135: approximately 40% of the total. The remaining points were equally distributed between the other two variables.

A. Energy Subsidy

Definition: Energy subsidy and its associated scale of maintenance requirement value is defined as the cost of total effort required to maintain a given land use in its present use.

Rationale: The amount of energy expended by humans to maintain an ecosystem is viewed as an artifical energy subsidy. Prolonged use of energy subsidies tends to make the internal system of the natural ecosystem less self-serving

and self-regulating. Thus, the more maintenance required to keep a land use in balance, the less stable is the use.

Assessment Procedure: The assessment procedure involves making a comparative analysis of the estimated annual maintenance performed on various NRPP land uses. The procedure had three steps. The results of each step are presented in Table 4.

In Step 1 a unit had to be chosen for making the comparative analysis. Ideally maintenance requirements should be measured in units of energy (i.e., BTU's, calories, etc.). Unfortunately, most data on land use maintenance requirement is not readily available in energy units. The next best unit was judged to dollars/acre/year. This economic expression of maintenance assumes that all energy inputs can be translated into monetary terms; that most externalities can be assigned a value. Data was then collected on the basis of annual maintenance cost required per acre for some 44 NRPP land use types. Essentially the data compiled average fixed costs (cash cost of materials and labor). Capital expenditures, variable and amortorized costs were excluded. The data represents the estimated mean or normal cost of maintenance; extremes were discarded.

In Step 2 the average annual maintenance cost per acre for each land use type was adjusted to its percentage of land area within its NRPP land use category. This step was

necessary in order to arrive at a cost figure for each of the eight primary NRPP land and water use categories. For example, there are five land use types in the NRPP agricultural land use category (see Table 4). While the maintenance cost for orchards was estimated to be $1375/acre/year, orchards represent less than 25% of all agricultural land in the Resource Region #144. On the other hand, tilled land costs $300/acre/year to maintain but comprises nearly 58% of all agricultural land. In an effort to balance distortions, the estimated cost of maintenance for each land use type was multiplied by its percentage of area in its NRPP land use category. The product is an adjusted maintenance requirement value for a land use type. These adjusted values within each of the eight land use categories was summed, resulting in a single maintenance requirement value for each of the eight categories.

Step 3 translated the adjusted maintenance requirement values to a stability rating. Each of the eight land use categories received a stability rating, which when totaled equaled 100 points. This assignment of the stability ratings was accomplished by proportional reduction and inversion of the adjusted maintenance requirement values.

Results: The assessment procedure resulted in a stability rating for each land use category. These ratings, from

Table 4: MAINTENANCE REQUIREMENT (ENERGY SUBSIDY) STABILITY RATING BY LAND USE

LAND USES (NRPP)	ESTIMATED COST OF MAINTENANCE (DOLLARS/ACRE/YEAR)	ESTIMATED ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	ADJUSTED MAINTENANCE REQUIREMENT VALUE	STABILITY RATING
AGRICULTURAL					
T-Tilled	300	100735	57.7	173	
P-Pasture	50	60116	34.4	17	
O-Orchard	1375	8595	4.9	67	
A-Abd. Orchard	138	2877	1.6	2	
N-Nurseries	1270	74	0.0	-	
Totals		174581		216	12
WILDLIFE LAND					
T-Tilled	300	25183	5.6	17	
TU-Unused Tilled	50	3101	0.7	-	
P-Pasture	50	15029	3.3	2	
AF-Abd. Field	11	59168	13.1	1	
O-Orchards	1375	2148	0.5	7	
AO-Abd. Orchards	138	719	0.2	-	
Managed Forest	3	333088	73.8	2	
PL-Power Lines	60	12751	2.8	2	
Totals		451187		31	17
RECREATION LAND					
C-Camping	500	408	2.0	10	
P-Picinicking	500	300	1.5	8	
X-Playgrounds	617	684	3.3	20	
L-Playfields	1020	4111	20.4	208	
M-Major Parks	210	5656	27.4	56	
R-Neighborhood Parks	617	105	0.5	3	
W-Winter Sp. Area	63	692	3.4	2	
G-Golf Courses	507	7700	37.4	190	
S-Shooting Clubs	617	147	0.7	4	
N-Nature Areas	12	794	3.9	1	
Totals		20597		502	4

Table 4: MAINTENANCE REQUIREMENT (ENERGY SUBSIDY) STABILITY RATING BY LAND USE (Continued)

LAND USES (NRPP)	ESTIMATED COST OF MAINTENANCE (DOLLARS/ACRE/YEAR)	ESTIMATED ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	ADJUSTED MAINTENANCE REQUIREMENT VALUE	STABILITY RATING
WOODLAND					
S-Stream Cor.	0	32354	2.4	-	
P-Watershed	1	150000	11.3	-	
A-Unmanaged Other	0	816912	61.3	-	
Managed Woodlot	2	333088	25.0	1	
Totals		1332354		1	18
URBAN LAND					
R-Residential	260	205701	73.1	190	
I-Industrial	98	5508	2.0	2	
B-Commercial	361	22012	7.8	28	
P-Pub Instit.	190	13517	4.8	9	
C-Cementaries	425	4904	1.7	7	
J-Junk Yards	-	912	0.0	-	
G-Gravel Pits	425	9424	3.5	15	
S-Landfill	2363	623	0.0	-	
T-Highways	5794	18724	6.7	388	
Totals		281325		639	0
WILDLIFE WETLAND					
Managed	205	3788	10.7	22	
Unmanaged	0	31545	89.3	-	
Totals		35333		22	18
RECREATION WATER					
S-Swimming Beach	617	371	2.5	15	
Swimming Pool	7147	41	0.3	21	
B-Boating Marina	617	63	0.4	2	
W-Warmwater Fishing	10	11906	78.7	8	
C-Coldwater Fishing	27	2800	18.5	5	
Totals		27087		51	16
MUNICIPAL WATER					
R-Reservoirs	114	48000	95.0	108	
W-Well Fields	228	2800	5.0	11	
Totals		50800		118	15

Table 4, are as follows:

Agricultural Land	12
Wildlife Land	17
Recreation Land	4
Woodland	18
Urban Land	0
Wildlife Wetland	18
Recreation Water	16
Municipal Water	15
Total	100

A higher numerical value indicates: 1) less maintenance is required to keep a land use category in its current use; 2) less energy subsidies are added to the natural processes of land use ecosystems and; 3) the more the land use is judged to contribute to the condition of ecosystem stability.

B. Bioenergetic Function

Definition: Bioenergetic function and its associated scale of maturity is a description of a land use's ecological structure and function on a continum of ecosystem development.

Rationale: Stability is reached through the process of ecological succession; climaxing in maturity. A land use's position on the succession continuum is a function of its particular structure, size and overall respiration. (Odum, 1969a and 1971).

Assessment Procedure: The assessment procedure involved the making of a comparative analysis of the relative maturity of various NRPP land uses. The procedure had three steps. The results of each step are presented in Table 5.

In Step 1 the appropriate indicator of maturity was selected. The bioenergetic function index of gross productivity over community respiration was judged appropriate. Due to the work of Odum (1969a,1969b) and Rodiek (1973, 1974) many land uses had already been assigned a bioenergetic P/R value. Each NRPP land use was assigned one of the following five bioenergetic P/R values or compartments (Odum, 1969a and Hendrix, 1973):

1) Non-vital: Value=1
Immature, ecological function largely replaced by techno-cultural function - P/R= < 1

2) Non-vital/Production Compromise: Value=34

3) Production: Value=68
Young, simple and growing vigorously - P/R= > 1

4) Production/Protection Compromise: Value=101

5) Protection: Value=135
Mature, diverse and healthy ecosystem where growth is slow and steady - P/R = 1

Figure 13 illustrates the relationships between these five compartments. The numerical value, on a scale of 0-135 were proportionally distributed to each compartment. Then one of the five numerical values were assigned to 49 NRPP land use types, indicating each's relative stability.

In Step 2 the numerical values of maturity for each land use type was adjusted to its percentage of land area within its NRPP land use category. This step is identical to Step 2 in the assessment procedures for the energy subsidy variable.

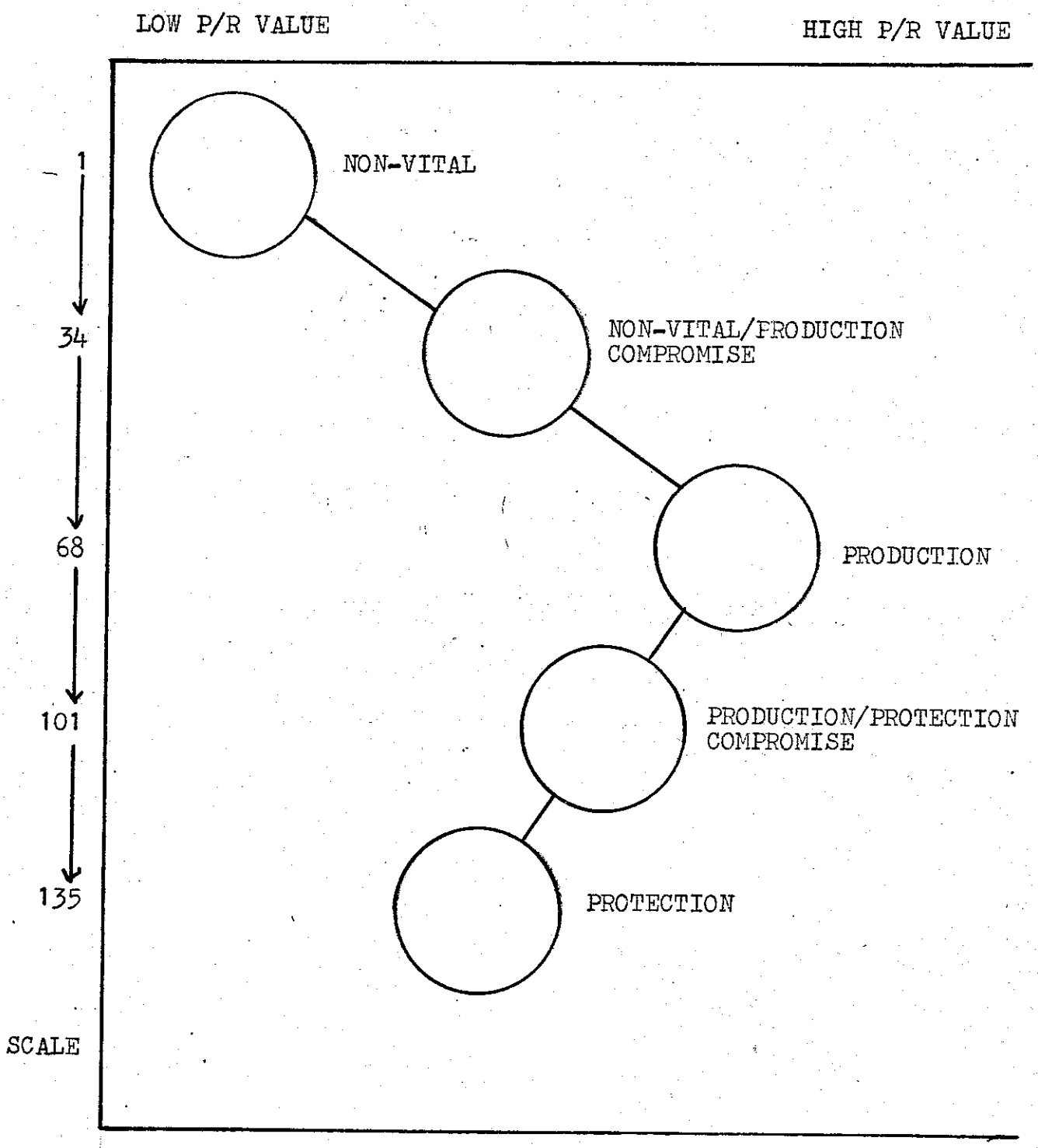


Figure 13: SCALE FOR MEASURING MATURITY

Table 5: MATURITY (BIOENERGETIC FUNCTION) STABILITY RATING BY LAND USE

ND USES (NRPP)	MATURITY VALUE 0-135 SCALE	ESTIMATED ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	ADJUSTED MATURITY VALUE	STABILITY RATING
RICULTURAL LAND					
T-Tilled	68	100735	57.7	39	
P-Pasture	68	60116	34.4	23	
O-Orchard	68	8595	4.9	3	
A-Abd. Orchard	101	2877	1.6	1	
N-Nurseries	68	2184	1.3	1	
C-Cranberry Bog	68	74	0.0	-	
Totals		174581		67	14
LDLIFE LAND					
T-Tilled	68	25183	5.6	4	
TU-Unused Tilled	101	3101	0.7	1	
P-Pasture	68	15029	3.3	2	
AF-Abd. Field	101	59168	13.1	13	
O-Orchard	68	2148	0.5	-	
AO-Abd. Orchard	101	719	0.2	-	
Young Forest	68	61116	13.5	9	
Old Forest	135	271972	60.3	81	
PL-Power Lines	101	12751	2.8	3	
Totals		451187		113	24
CREATION LAND					
C-Camping	101	408	2.0	2	
P-Picinicking	101	300	1.5	2	
X-Playgrounds	34	684	3.3	1	
L-Playfields	34	4111	20.4	7	
M-Major Parks	101	5656	27.4	28	
R-Neighborhood Parks	34	105	0.5	-	
W-Winter Sp. Area	101	692	3.4	3	
G-Golf Courses	68	7700	37.4	25	
S-Shooting Clubs	34	147	0.7	-	
N-Nature Areas	135	794	3.9	5	
Totals		20597		73	15

Table 5: MATURITY (BIOENERGETIC FUNCTION) STABILITY RATING BY LAND USE (Continued)

ND USES (NRPP)	MATURITY VALUE 0-135 SCALE	ESTIMATED ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	ADJUSTED MATURITY VALUE	STABILITY RATING
)DLAND					
Young Forest	68	244466	18.4	13	
)ld Forest	135	1087888	81.6	110	
Totals		1332354		126	27
BAN LAND					
R-Residential	34	205701	73.1	25	
I-Industrial	1	5508	2.0	-	
B-Commercial	1	22012	7.8	-	
P-Pub. Instit.	1	13517	4.8	-	
C-Cementaries	34	4404	1.7	1	
J-Junk Yards	1	912	0.0	-	
G-Gravel Pits	1	9424	3.5	-	
S-Landfills	1	623	0.0	-	
T-Highways	1	18724	6.7	-	
Totals		281325		26	5
LDLIFE WETLANDS					
SM-Shallow Marsh	68	9484	26.8	18	
DM-Deep Marsh	68	6505	18.4	13	
SS-Shrub Swamp	101	15616	44.2	47	
SF-Seasonally Fld.	68	5795	16.6	11	
B-Bog	68	276	0.8	1	
M-Meadow	68	4098	11.6	8	
Totals		35333		98	21
REATION WATER					
S-Swimming	101	412	0.6	1	
B-Boating	1	63	0.1	-	
H-Hunting	68	51812	77.3	53	
W-Warmwater Fishing	68	11905	17.8	12	
C-Coldwater Fishing	68	2800	4.2	3	
Totals		66993		69	15
NICIPAL WATER					
R-Reservoirs	68	48000	95.0	65	
W-Well Fields	101	2800	5.0	5	
Totals		50800		70	15

Step 3 translated the sum of the adjusted bioenergetic function values for each land use category to a stability rating. The stability rating for each land use category was determined by a proportional reduction of the adjusted bioenergetic function value. The total for the eight individual stability ratings equaled 135 points.

Results: The assessment procedure resulted in a stability rating for each land use category. These ratings, from Table 5, are as follows:

Agricultural Land	14
Wildlife Land	24
Recreation Land	15
Woodland	27
Urban Land	5
Wildlife Wetland	21
Recreation Water	15
Municipal Water	15
Total	135

A high numerical value indicates that the land use: 1) has a P/R value closest to one; 2) is a more mature ecological system and; 3) contributes more to the condition of ecosystem stability.

C. Ecosystem Health Impairment

Definition: Ecosystem health impairment and its two associated scales of water and air quality defines the kinds of pollution generated by land uses which adversely impact an ecosystem's biotic and vegetative health.

Rationale: Pollutants contribute to the degradation

of natural organisms, thus weakening the structure and diversity of ecosystems and leading to instability. Air and water are considered to be important transport mechanisms which carry pollution material from one land use to another. (Careaga, 1973 and Fehrer, 1975).

Two Scales: The ecosystem health impairment variable has two distinct scales; one for evaluating water quality and the other for air quality. While each transports pollutants which impair ecosystem health, the transport mechanism of water was judged to be twice as potentially damaging as air. Hence, of the 100 points assigned to this variable, 65 were distributed to the water quality scale and 35 to the air quality scale.

Water Quality Assessment Procedure: The objective of the water quality scale is to quantitatively express the impairment of ambient water quality by a particular land use and the resultant effects on ecosystem health. Land use types differ in the amount of pollution which they generate and in the type of pollution they generate.

The assessment procedure involved the making of a comparative analysis of water pollutants impairing ecosystem health generated by the various NRPP land uses. The procedure had three steps. The results of each step are presented in Table 7.

Step 1 involved the identification of major water

pollutants, their sources of generation and their degree of impairment.

Careaga (1973:19) identified ten categories of pollutants that represent material outputs that are associated with land uses. Nine of these categories were relevant to the assessment of ecosystem health:

1) Pathogens - these are disease causing micro-organisms that can be water borne and which are derived from sanitary wastes.
2) Phosphates - are founded in many cleaning compounds, fertilizers and organic wastes. They are largely responsible for the eutrophication of water bodies.
3) Nitrates and Nitrites - come from fertilizers and human and animal wastes. They also act to stimulate eutrophication.
4) Pesticides - (including herbicides) are a complex group including chlorinated hydrocarbons, organophosophates, carbamates and arsenicals. These compounds are acutely toxic to a wide variety of biota and flora.
5) Oil and Gasoline - are due primarily to the wide spread use of the internal combustion engine. They can cause moderate to severe problems for plants.

6) Lead - is generally associated with gasoline as a fuel additive.

7) Industrial Chemicals - these include many kinds of organic and inorganic compounds that are toxic to natural consumers.

8) Sediments - include particles of soil and rock from natural sources distributed by humans. The effects of sedimentation are significant on a few sensitive organisms.

9) Heat - due mainly to water used for cooling in industrial processes and in power generation. Heat can upset some aquatic habitats.

Careaga (1973:22) identified four aspects of the above pollutants: 1) the threat which they pose to the public health, 2) the time it takes for them to become innocuous in the natural system, 3) their resistance to treatment and 4) the impact which they can have on natural organisms or the health of the ecosystem. It is primarily this aspect that effects the stability of the ecosystem.

Careaga established a scale to rate the potential seriousness of the pollutants for each of the above four aspects. For this sub-model only the scale relating to the aspect of ecosystem health was used. Careaga's weighed scale for the aspect "ecosystem health" was as follows:

Pathogens	1.1
Phosphates	8.9
Nitrates and Nitrites	8.9
Pesticides	8.9
Oil and Gasoline	6.7
Lead	8.9
Industrial Chemicals	8.9
Sediments	2.3
Heat	8.9

On this scale of 0-10 the degree of impact on ecosystem health means:

10.0 = High
8.9 = Moderate to High
7.8 = Moderate
6.7 = Low to High
5.6 = Low to Moderate
4.5 = Absent to High
3.4 = Absent to Moderate
2.3 = Low
1.1 = Absent to Low
0.0 = Absent

From this scale a matrix showing the ratings for the presence of each type of pollutant on a weighed basis for the parameter ecosystem health was prepared (see Table 6).

The values from Table 6 were then assigned to each land use type to indicate its impairment of ambient water quality. The raw impairment scores for each pollutant generated by each land use type were summed.

In Step 2 the impairment raw scores for each land use type were adjusted to its percentage of land area within the NRPP land use categories. This step was identical to Step 2 in the assessment procedures for both the variables energy subsidy and bioenergetic function.

Step 3 translated the adjusted raw score for each land use category to a stability rating. The stability rating was determined by a proportional reduction and inversion of the adjusted raw score. The total for the eight individual stability ratings equaled 65 points.

Water Quality Results: The assessment procedure for water quality impairment resulted in a stability rating for each land use category. These ratings, from Table 7, are as follows:

Agricultural Land	0
Wildlife Land	8
Recreation Land	3
Woodland	13
Urban Land	3
Wildlife Wetland	13
Recreation Water	12
Municipal Water	13
Total	65

A high numerical value indicates that the land use 1) generates pollutants, carried by water, which have the least degree of impairment on the health of organisms and vegetation and 2) contributes more to a condition of ecosystem stability.

Air Quality Assessment Procedure: The objective of the air quality scale is to quantitatively express the impairment of ambient air quality by a particular land use and the resultant effect on ecosystem health. The assessment procedure involved making a comparative analysis of pollutants impairing ecosystem health generated by NRPP land uses. The procedure had three steps. The results

Table 6: DEGREE/IMPACT RATING FOR POLLUTANTS EFFECTING ECOSYSTEM HEALTH

	Absent to Low	Low	Absent to Moderate	Absent to High	Low to Moderate	Low to High	Moderate	Moderate to High	High
PATHOGENS	1.21	2.53	3.74	4.95	6.16	7.37	8.58	9.79	11.00
PHOSPHATES	9.79	20.47	30.26	40.05	49.64	57.63	69.62	81.21	89.00
NITRATES AND NITRITES	9.79	20.47	30.26	40.05	49.64	57.63	69.62	81.21	89.00
PESTICIDES	9.79	20.47	30.26	40.05	49.64	57.63	69.62	81.21	89.00
OIL AND GASOLINE	7.37	15.41	22.78	30.14	37.52	44.89	52.26	59.83	67.00
LEAD	9.79	20.47	30.26	40.64	49.64	57.63	69.62	81.21	89.00
INDUSTRIAL CHEMICALS	9.79	20.47	30.26	40.64	49.64	57.63	69.62	81.21	89.00
SEDIMENTS	2.53	5.29	7.82	10.35	12.88	15.41	17.94	20.47	23.00
HEAT	9.79	20.47	30.26	40.64	49.64	57.63	69.62	81.21	89.00

Table 7: WATER QUALITY IMPAIRMENT STABILITY RATING BY LAND USE

LAND USE (NRPP)	LAND USE (MAP DOWN)	PATHOGENS	PHOSPHATES	NITRATES AND NITRITES	PESTICIDES	OIL AND GASOLINE	LEAD	INDUSTRIAL CHEMICALS	SEDIMENTS	HEAT	IMPAIRMENT RAW SCORE	EST. ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	IMPAIRMENT OF WATER QUALITY ADJ. RAW SCORE	STABILITY RATING
GRICULTURAL LAND															
	T	---	89.00	89.00	89.00	---	---	---	17.49	--	284.94	100735	57.7	164.41	
	N	---	89.00	89.00	89.00	---	---	---	5.29	--	267.00	2184	1.2	3.20	
	O	---	20.47	20.47	89.00	---	---	---	23.00	--	135.23	8595	4.9	6.63	
	TU	---	20.47	20.47	20.47	---	---	---	5.29	--	84.41	3101	1.8	1.52	
	P	2.53	20.47	20.47	20.47	---	---	---	----	--	69.23	60116	34.4	23.81	
	CB	---	20.47	20.47	20.47	---	---	---	----	--	61.41	74	0.0	0.00	
	Totals											174731		199.57	0
LDLIFE LAND															
	AF,AO,AP	---	20.47	20.47	20.47	---	---	---	5.29	--	66.70	62052	83.0	55.36	
	PL	---	---	---	89.00	7.37	20.47	---	20.47	--	137.31	12751	17.0	23.34	
	Totals											74803		78.70	8
CREATION LAND															
	RG	2.53	89.00	89.00	89.00	7.37	9.79	---	----	--	286.69	7700	21.5	61.64	
	RA	2.53	20.47	20.47	20.47	7.37	9.79	---	2.53	--	83.63	4111	11.5	9.61	
	RPG	2.53	9.79	9.79	9.79	---	---	---	2.53	--	34.43	684	1.9	.65	
	RD	1.21	---	---	30.26	---	---	---	----	--	31.47	147	0.4	.13	
	RC	1.21	---	---	---	---	---	---	2.53	--	3.74	182	0.5	.02	
	UO,UP	---	---	---	9.79	44.87	57.63	---	----	--	112.29	22978	64.2	72.09	
	Totals											35802		144.14	3
ODLAND															
	All Forests	---	---	---	---	---	---	---	----	--	0.0	---	---	0.00	
	Totals													0.00	13
BAN LAND															
	HW	---	---	---	89.00	67.00	89.00	---	17.94	--	262.94	13462	4.9	12.88	
	UTT	1.21	---	---	30.26	67.00	89.00	40.05	7.82	--	235.34	1439	0.5	1.18	
	UTA	2.53	---	---	81.21	59.83	81.21	---	7.82	--	232.60	2435	0.9	2.09	83.
	UTR	1.21	---	---	81.21	59.83	9.79	40.05	10.35	--	202.44	1344	0.5	1.01	

Table 7: WATER QUALITY IMPAIRMENT STABILITY RATING BY LAND USE (continued)

LAND USE (NRPP)	LAND USE (MAP DOWN)	PATHOGENS	PHOSPHATES	NITRATES AND NITRITES	PESTICIDES	OIL AND GASOLINE	LEAD	INDUSTRIAL CHEMICALS	SEDIMENTS	HEAT	IMPAIRMENT RAW SCORE	EST. ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	IMPAIRMENT OF WATER QUALITY ADJ. RAW SCORE	STABILITY RATING
	US,UT,UCR	9.79	20.47	---	9.79	44.87	57.63	---	---	--	142.57	15732	5.7	8.13	
	RI	2.53	--	---	30.26	52.26	69.62	---	7.82	--	162.49	331	0.1	.16	
URF,URO,URH,URM,URL		2.53	20.47	---	9.79	44.87	57.63	---	7.82	--	143.71	187871	68.0	97.72	
	RT	2.53	--	---	---	67.00	89.00	---	---	--	158.53	333	0.1	.15	
	UH,UI,UL,US	2.53	--	---	---	59.83	57.63	---	---	--	119.99	22107	8.0	9.60	
	UC	2.53	--	---	---	7.37	57.63	---	---	--	67.53	3154	1.1	.74	
	RGF	11.00	--	---	9.79	7.37	9.79	---	2.53	--	40.48	35	0.0	0.00	
	OM	---	--	---	---	7.37	9.79	---	20.47	40.05	77.68	325	0.1	.08	
	DA	---	--	---	---	59.83	40.05	---	--	--	99.88	912	0.3	.30	
	UP	7.37	9.79	---	9.79	7.37	9.79	---	--	--	44.11	13517	4.9	2.16	
	UE	2.53	20.47	9.79	9.79	7.37	9.79	---	--	--	59.74	2098	0.8	.48	
	SG	---	--	---	---	7.37	9.79	---	17.94	--	35.10	9424	3.4	1.19	
	RAP	2.53	--	---	---	7.37	9.79	---	2.53	--	22.22	1620	0.6	.13	
	Totals											276139		138.00	3
ILDLIFE WETLAND															
	DM,SF,B,M	---	--	---	---	---	---	---	---	--	0.00	---	--	0.00	
	Totals													0.00	13
ECREATION WATER															
	RFB,RS	2.53	--	---	---	---	---	---	---	--	2.53	412	86.7	.05	
	RM	---	---	---	---	7.37	9.79	---	---	--	17.16	63	13.3	2.28	
	Totals											475		2.33	12
INICIPAL WATER															
	W	---	---	---	---	---	---	---	---	--	0.00	---	---	0.00	
	Totals													0.00	13

of each step are presented in Table 8.

Step 1 involved the identification of major air pollutants, their source of generation, and their degree of impairment.

Fehrer (1975) identified five significant air pollutants that have potential for impairing ecosystem health. They are:

1) Particulate Matter - are particles of solid or liquid matter. They may vary greatly in size. In addition to problems created by their mere volume, particulates are capable of acting as catalysts and of absorbing radiant energy.
2) Sulfur Oxides - are pungent, colorless gases formed primarily by the combustion of fossil fuels. They can yellow leaves of vegetation and cut down the light from the sun.
3) Nitrogen Oxides - are gases formed in great part from atmospheric nitrogen and oxygen when combustion takes place under conditions of high temperature and high pressure, as in the internal combustion engine. Various nitrogen oxides are poisonious in large concentrations to vegetation.
4) Carbon Monoxides - is a product of incomplete

combustion. Of the most significant pollutants this is the least harmful to vegetation.

5) Hydrocarbons - consist of any number of compounds containing carbon and hydrogen and are especially found in fossil fuels. They may be carcinogenic or active participants in the photochemical process.

Air pollution emission data was available for these five pollutants. The amount, measured in lb./acre/year, of emission by each land use type was available by Air Pollution Control Districts. The data from the Pioneer, Central and Merrimack Districts in Massachusetts were selected for inclusion in this sub-model. However, because different air pollutants have greatly different toxicities per unit of mass, the emissions must be rated by their effect, not their mass. A rating scale developed by Walther (1972) was used to translate mass into effect. This scale is based upon the potential impact emissions have on vegetation and property (National Secondary Ambient Air Quality Standards) and is as follows:

Hydrocarbons	125.0
Particulate Matter	37.3
Nitrogen Oxides	22.4
Sulfur Oxides	21.5
Carbon Monoxides	1.0

Thus, the emission data (lb./acre/year) for each land use type in the three Districts was multiplied by the above effect scale to produce a weighed emission value. The total weighed emission value for each pollutant generated by each land use type was summed.

In Step 2 the total weighed emission values for each land use type were adjusted to its percentage of land area within the NRPP land use categories. This step was identical to Step 2 in the assessment procedure for water quality impairment.

Step 3 translated the adjusted raw score for each land use category to a stability rating. The stability rating was determined by a proportional reduction and inversion of the adjusted raw score. The total for the eight individual stability ratings was 35 points.

Air Quality Results: The assessment procedure for air quality impairment resulted in a stability rating for each land use category. These ratings, from Table 8, are as follows:

Agricultural Land	5
Wildlife Land	5
Recreation Land	5
Woodland	5
Urban Land	0
Wildlife Wetland	5
Recreation Water	5
Municipal Water	5
Total	35

Table 8: AIR QUALITY IMPAIRMENT STABILITY RATING BY LAND USE

LAND USE (NRPP)	LAND USE (MAP DOWN)		PARTICULATE MATTER	SULFUR OXIDES	NITROGEN OXIDES	CARBON MONOXIDE	HYDROCARBONS	TOTAL WEIGHED EMISSIONS	EST. ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	IMPAIRMENT OF AIR QUALITY ADJUSTED RAW SCORE	STABILITY RATING
BAN LAND	URL	E	24.8	11.8	147.3	1084	207.8					
		W	927	935	3300	1084	25970	32234	162999	64.7	20855	
	URD	E	707.2	1248.8	4116.0	31160	5912.0					
		W	26380	26850	92200	31160	739000	915590	42702	16.9	154734	
	UC-Area	E	2485.3	11172.0	12178.6	31400	13736.0					
		W	92700	240200	272800	31400	1717000	2354100	12992	5.2	122413	
	UC-Area +Point	E	2769.4	12846.5	13058.0	31400	13784.0					
		W	103300	276200	292500	31400	1723000	2426400	12991	5.2	126172	
	UI-Area	E	2160.9	3460.5	7522.3	31700	21560.0					
		W	80600	74400	168500	31700	2695000	3050299	14528	5.8	176112	
	UI-Area +Point	E	4187.7	11618.6	12241.1	32300	21880.0					
		W	156200	249800	274200	32300	2735000	3447500	14528	5.8	199955	
	HW	E	365.1	117.6	4879.5	17870	4104.0					
		W	13620	2528	109300	17870	513000	656318	13462	5.3	34785	
	UTA	E	382.0	156.7	3839.3	32500	5920.0					
		W	14250	3369	86000	32500	740000	876119	2435	0.9	7885	
	UTR	E	365.1	118.3	3660.7	30890	5392.0					
		W	13620	2543	86000	30890	674000	803053	1344	0.5	4015	
	UTT	E	379.1	147.0	4058.0	31170	5432.0					
		W	14140	3160	90900	31170	679000	818370	1439	0.1	818	
	UTW	E	129.0	41.4	1290.2	10900	1904.0					
		W	4810	890	28900	10900	238000	283500	44	0.0	---	
	Totals								251945		847744	

Table 8: AIR QUALITY IMPAIRMENT STABILITY RATING BY LAND USE (continued)

LAND USE (NRPP)	LAND USE (MAP DOWN)		PARTICULATE MATTER	SULFUR OXIDES	NITROGEN OXIDES	CARBON MONOXIDES	HYDROCARBONS	TOTAL WEIGHED EMISSIONS	EST. ACRES FOR LAND USE IN AREA #144	ESTIMATED % OF LAND USE ACRES	IMPAIRMENT OF AIR QUALITY ADJUSTED RAW SCORE	STABILITY RATING
ECREATION LAND	RD	E	0.7	0.8	8.3	34	6.9					
		W	25	18	187	34	866	1130	--	--	1130	5
ECREATION WATER	W	E	0.0	0.5	0.5	249	91.2					
		W	0	10	11	249	11400	10670	--	--	10670	5
RICULTURAL LAND		E	3.1	2.0	9.7	33	9.1					
		W	116	43	217	33	1133	1542	--	--	1542	5
NICIPAL WATER		E	-	-	-	-	-					
		W	-	-	-	-	-	-	-	-	-	5
LDLIFE LAND		E	-	-	-	-	-					
		W	-	-	-	-	-	-	-	-	-	5
LDLIFE WETLAND		E	-	-	-	-	-					
		W	-	-	-	-	-	-	-	-	-	5
DLAND		E	-	-	-	-	-					
		W	-	-	-	-	-	-	-	-	-	5

E = Total Emissions (lb/acre/year)
W = Weighed value (Walther, 1972)

A high numerical value (5) indicates that the land use 1) generates pollutants, carried by the air, which have the least degree of impairment on the health of organisms and vegetation, and 2) contributes more to a condition of ecosystem stability.

OUTPUTS

The output of this sub-model is a numerical scale which expresses the contribution potential, in relative terms, of the eight NRPP land uses to a condition of ecosystem stability. The eight land uses have been taken through three assessment variables and four assessment scales. The values from the four scales received for each land use may be totaled. The results are:

Agricultural Land	31
Wildlife Land	54
Recreation Land	27
Woodland	62
Urban Land	8
Wildlife Wetland	57
Recreation Water	48
Municipal Water	48
Total	335

As a composite value, a high numerical score for a land use should indicate that it contributes more to preserving and sustaining the self-regulating, regenerating and self-protecting characteristics of ecosystem stability.

These numerical values are capable of serving as importance values for the parameter ecosystem stability on the NRPP Parameter Rating Table. Table 9 illustrates

their inclusion into the Parameter Rating Table. Note that the variables of this sub-model have become sub-parameters to the parameter ecosystem stability. These three sub-parameters can substitute for the current single sub-parameter, maintenance requirement (see Table 1, page 16.)

Table 9: REVISED PARAMETER RATING TABLE

Parameters \ Resources	AGRICULTURAL LAND	MUNICIPAL WATER	RECREATION LAND	RECREATION WATER	URBAN LAND	WILDLIFE WETLAND	WILDLIFE LAND	WOODLAND	TOTAL
I. HEALTH									
a. Basic Needs									
1.) Air	5	15	5	15	-	10	5	20	75
2.) Shelter	7	-	-	-	26	-	-	7	40
3.) Food	40	-	-	-	-	-	-	-	40
4.) Water	6	18	6	18	-	18	6	18	90
b. Microclimate									
1.) Temperature	2	4	-	5	5	2	2	10	30
c. Physical Fitness	2	-	10	10	-	2	3	3	30
d. Mental Well-Being	5	-	5	5	-	5	5	5	30
SUBTOTAL	67	37	26	53	31	37	21	63	335
II. ECOSYSTEM STABILITY									
a. Energy Subsidy	12	15	4	16	-	18	17	18	100
b. Bioenergetic Function	14	15	15	15	5	21	24	26	135
c. Ecosystem Health Impairment									
1.) Water Quality	-	13	3	12	3	13	8	13	65
2.) Air Quality	5	5	5	5	-	5	5	5	35
SUBTOTAL	31	48	27	48	8	57	54	62	335
III. OPPORTUNITIES FOR OUTDOOR RECREATION									
a. Capacity for Uses	5	2	15	15	-	3	3	7	50
b. Intensity of Use	3	1	8	9	-	4	2	3	30
c. Diversity of Uses	2	1	8	4	-	2	1	2	20
SUBTOTAL	10	4	31	28	-	9	6	12	100
TOTAL (Item I, II, III)	108	89	84	129	39	103	81	137	770
IV. AESTHETICS (Modifiers, Air, Visual Quality)									230
TOTAL (Item I, II, II, IV)									1000

C H A P T E R I V

INTERPRETATIONS AND IMPLICATIONS OF FINDINGS

This study has develped a sub-model for assessing ecosystem stability within the context of the Natural Resource Planning Program. The sub-model's contributions and validity for application in the NRPP must now be analysed.

VALIDITY OF DATA

A word should first be said concerning the reliability and validity of the sub-model's principle data. Of the three variables, ecosystem health impairment was backed by the most researched and reliable data. The data acquired for the energy subsidy variable was social in nature and cannot withstand much scientific scrutiny. The most vunerable dat, however, was that assimulated for the bioenergetic function variable. That dat, as is its subject, is highly theoretical and has had little or no empirical investigation. Finally, the acreage data collected for the assessment procedures required a very crude correlation of two distinct and different land use classification systems. This problem can be allievated in time, for as the NRPP inventories expand across Resource Region #144, their acreage

figures can be subsituted for the current correlations. In fact, because land uses are themselves changing within the resource region, the sub-model should ideally be update every five or ten years.

The problems associated with data collection for these variables, however, should not be over played. The very hypothetical nature of the Parameter Rating Table and the vagueness of sub-parameters for other parameters in the table indicate that accurate and reliable data will forever remain a problem.

CONTRIBUTIONS OF SUB-MODEL

This study has produced several significant changes for the NRPP model.

First, it has expanded on the variables capable of escribing ecosystem stability. While this study has kept the NRPP sub-parameter of maintenance requirement, it has slightly changed its emphasis and title to energy subsidy. More importantly, this study has concluded that the sole sub-parameter was an incomplete and insufficient variable for describing ecosystem stability. Assuming that the data for the sub-model is somewhat reliable, the stability ratings under each variable tend to show that land uses change position relative to one another between variables. This fact would seem to indicate the desirability for the presence of

Table 10: COMPARISON OF NEW AND CURRENT IMPORTANCE VALUES

	IMPORTANCE VALUES					
	TOTAL FOR ECOSYSTEM STABILITY PARAMETER			TOTALS FOR THREE PARAMETERS		
	CURRENT	NEW	CHANGE	CURRENT	NEW	CHANGE
WOODLAND	90	63	-27	165	137	-28
WILDLIFE WETLAND	70	57	-13	116	103	-13
WILDLIFE LAND	70	54	-16	81	81	0
RECREATION WATER	45	52	+ 7	126	129	+ 3
MUNICIPAL WATER	30	48	+18	71	89	+18
AGRICULTURAL LAND	20	31	+11	97	108	+11
RECREATION LAND	10	22	+12	67	67	+17
URBAN LAND	0	8	+ 8	31	39	+ 8
TOTALS	335	335		770	770	

more than one variable.

Secondly, the assessment procedure has altered the importance values assigned to each land use for the parameter ecosystem stability. The new importance values do not change the relative position of any land use for the parameter ecosystem stability. A comparison of changes in the importance values is illustrated in Table 10. The new sub-model has closed the relative spread of importance values between land uses. Even if this fact is a true reflection of reality, it is regretable, for an implied intention of the Parameter Rating Table has been to illuminate the differences between land uses.

A third contribution the new sub-model makes is to change the weighed value for the computation of the Natural Resource Quality Index (Figure 4, column c, page 20). These changes are also illustrated in Table 10. The significance of this change has yet to be proven. The new figures were applied to the NRQ Index for Granby, Massachusetts (the only town with a current valid Index) and it served to reduce the Index by only two points; from a value of 60 to one of 58.

VALIDITY OF SUB-MODEL

This sub-model has attempted to develop both a conceptual framework for ecosystem stability and a rating scale

that improves the sensitivity of the entire NRPP model. Acceptance of the results by the Soil Conservation Service would certainly establish utility and possible validity. Due to the hypothetical nature of the subject matter of this study, its acceptance might, in fact, be its best test of validity.

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APPENDIX A: THE NRPP LAND USE CLASSIFICATION SYSTEM

AGRICULTURAL LAND

INVENTORY DESCRIPTION

Inventory criteria: all land areas that are used primarily for the production of some type of agricultural crop and are over 3 acres or greater in size.

T - Tilled or tillable crop land, which is or has been recently intensively farmed.

P - Permanent grassland used for hay or pasture, or idle land usually mowed annually.

O - Productive fruit orchards.

A - Abandoned orchards. In addition to the decadent fruit trees, grass and woody vegetation are abundant.

N - Nurseries, including greenhouses and land adjacent to them as well as lands supporting horticultural specialties, ornamentals, shrubs and Christmas trees.

C - A productive cranberry bog or other land with a specialty crop.

WILDLIFE LAND

INVENTORY DESCRIPTION

Inventory criteria: all land areas 3 acres or greater in size which are used primarily for the production or preservation of openland wildlife and woodland wildlife, including:

1) dedicated land which is committed to permanent wildlife use

2) non-dedicated land which is in no way committed to permanent wildlife use

Commercial wildlife production and private shooting club lands are not to be included as wildlife land as they are considered under recreation land.

T - Tilled land

Tu - Unused tillable land without woody vegetation

P - Pasture or wild hayland

Af - Abandoned field with less than 30% woody vegetation

O - Productive fruit orchard

He - Heath plant communities

Ao - Abandoned orchard

Sl - Softwood forest - height Class 1

S - Softwood forest - height class greater than 1

Hl - Hardwood forest - height Class 1

H - Hardwood forest - height class greater than 1

Hsl - Hardwood-Softwood Mixture, with hardwoods predominant - height Class 1

Hs - Hardwood-Softwood Mixture, with hardwoods predominant - height class greater than 1

Shl - Softwood-Hardwood Mixture, with softwoods predominant - height Class 1

Sh - Softwood-Hardwood Mixture, with softwoods predominant - height class greater than 1

Pl - Power lines and pipe lines

Sa - Sand areas

RECREATION LAND

INVENTORY DESCRIPTION

Inventory criteria: all land areas which are used primarily for outdoor recreation, exluding wooded areas used for passive recreation such as hiking.

C - Camping area

P - Picnicking area

X - Playgrounds (including school playgrounds)

L - Playfields

M - Major parks

R - Neighborhood parks

W - Winter sports areas (including skiing areas, sledding areas, ice skating areas, etc.)

G - Golf course (including 18-hole and 9-hole courses, driving ranges, Par-3 courses and driving ranges)

S - Shooting clubs (including fish and game clubs, game raising areas and target ranges for archery, rifle, skeet and pistol)

N - Nature areas for nature study and outdoor laboratories

WOODLAND

INVENTORY DESCRIPTION

Inventory criteria: all woodland areas 10 acres or greater in size that have an estimated 30% tree crown closure and are used primarily for growing trees. Where scattered residences are located in wooded areas, the wooded area 100 feet beyond the structure (house, building, commercial establishment, etc.) in any direction is considered woodland. (The structure and the area 100 feet beyond it in any direction is "Urban Land").

S - Stream Corridor Protection Woodland - Those woodlands located along streams which provide a protective zone to the stream. For those areas where the streams flow through forests (the woodland) delineate a strip 150 feet on each side of the stream beyond its banks as stream corridor protection lands.

P - Watershed Protection Woodland - Those woodlands draining into a water supply or reserved for a public forest, nature area or conservation purposes. (See rationale of "Criteria for Rating Woodland", Appendix G).

A - Other Woodland - That which provides or contributes to: open space; green space; contributes some benefits through wood production (lumber, pulp, fuel, etc.); has an effect on maintenance of air quality, etc., whether this woodland is managed or unmanaged.

URBAN LAND

INVENTORY DESCRIPTION

Inventory criteria: all lands used for residential, commercial, industrial, institutional, or transportation purposes. This includes strip or linear developments along roads for a distance of 200 feet back from the road, turnpikes and interstate highways along the outside edge of the right-of-way and farmsteads and other isolated structures (house, building, commercial establishment, etc.) for a distance of 100 feet in any direction from the building(s). Playgrounds and athletic fields are not included.

M - Mixed Commercial, Industrial and/or Residential

I - Industrial

B - Commercial

R - Residential

P - public buildings, colleges, schools, hospitals, churches

C - Cemeteries

J - Junkyards

G - Gravel pits (active or abandoned)

T - Transportation (paved roads, airports, etc.)

S - Sewage treatment or disposal areas, landfills

WILDLIFE WETLAND

INVENTORY DESCRIPTION

Inventory criteria: those areas used primarily for the production or preservation of wetland wildlife and aquatic animals other than fish. Wildlife Wetlands include seasonally-flooded basins or flats and areas that have water at or above the surface (to a maximum of 3 feet) for more than nine months of the year. Shooting clubs and fish and game clubs for the club memberships' exclusive use or wooded areas with more than 30% tree crown cover are not considered as wildlife wetlands.

Sm - Shallow marsh

Dm - Deep marsh

Ss - Shrub swamp

Sf - Seasonally-flooded basin or flat

Bp - Beaver pond

B - Bog

M - Meadow

Ism - Irregularly-flooded salt meadow

Dsm - Irregularly-flooded salt meadow that has been ditched

Tsm - Tidal salt water marsh

RECREATION WATER

INVENTORY DESCRIPTION

Inventory criteria: those areas used primarily for some type of water associated recreation. Include perennial streams and rivers named on the USGS Quadrangle Sheets, lakes and ponds over 3 feet deep (except municipal water supplies), and areas fronting the ocean up to a 1-mile wide strip out from shore.

S - Freshwater Swimming

Ss - Saltwater Swimming

B - Freshwater Boating

Bb - Saltwater Boating

H - Hunting

K - Water skiing

W - Warm water fishing

C - Cold water fishing

X - Surf fishing

Z - Shell fishing

MUNICIPAL WATER

INVENTORY DESCRIPTION

Inventory criteria: all water surface areas used for public-domestic supply, industrial use, power development and other similar uses, including reservoirs; irrigation ponds (for agricultural crops, golf courses, etc.); rivers, bays and harbors used primarily for commercial purposes; fish hatcheries or commercial fishing ponds; and land used for well fields.

R - Reservoir for private and public water supply including standpipes

I - Irrigation pond

N - Navigational waters, such as rivers, harbors and bays

F - Fish hatcheries

C - Commercial fishing ponds

W - Well field

APPENDIX B: THE MASSACHUSETTS MAP DOWN LAND USE CLASSIFICATION SYSTEM

MASSACHUSETTS MAP DOWN

Land-use and Vegetative Cover Mapping Classification Manual for Use with Massachusetts Map Down Maps

by William P. MacConnell, Project Leader

Massachusetts Map Down is the mapping component of a larger land-use and natural resource inventory of Massachusetts entitled "Remote Sensing Twenty Years of Change in the Human Environment in Massachusetts, 1951-1971." The objectives and procedures of the larger study are listed below.

Objectives:

a. To develop and test the use of aerial photogrammetric techniques as a tool for identifying and classifying agricultural, forest and wetlands; mining and waste disposal areas, as well as urban land and outdoor recreation sites.

b. To examine and classify the entire state of Massachusetts on new aerial photography and prepare a catalogue of maps covering the entire state for the use of resource planners and others requiring detailed maps of the landscape and cityscape in Massachusetts.

c. To determine changes in vegetation and land use which have taken place since the state was photographed and mapped in 1951 and 1952 by a similar system.

d. To establish predictions of future rates and patterns of change for major land-use types based on changes over the past 20 years. Population growth and construction of transportation facilities will be used to help predict future change.

e. To analyze and compare the wetlands of the state on 1951 maps and photographs with those on 1971 maps and photographs to measure changes in area, location and character of the wetlands, and especially to expose the impact of urbanization, highway construction and waste disposal areas on the location and extent of these lands.

f. To provide vegetative cover and land-use maps of the entire state for watershed managers, foresters, wildlife biologists, resource planners and others interested in the environment.

g. To develop visual-aesthetic criteria for describing the scenic quality of the vegetative and land-use types spread on the landscape.

h. To establish a data bank in computer form to store, manipulate, retrieve and present information in tabular or computer map form from the maps made in the 1951 study as well as those made from 1971 aerial photography and those made from ERTS/EROS imagery.

i. To study urban growth and decay, especially the situation in the urban-agriculture or urban-forest interface in Massachusetts.

j. To provide ground truth for training in interpretation of ERTS/EROS imagery.

Procedure:

a. Acquire new aerial photography of the state at a scale of 1:20,000.

b. Refine and adapt the aerial photographic classifications used for all Massachusetts in 1951 and for the entire Connecticut River in 1965 as well as ongoing research in urban land classification.

c. Interpret 1971 and 1972 aerial photographs of the state and annotate them with the land-use and vegetative types in the classification system evolved for the state in item b. above.

Six categories will be recognized:

1. Agricultural or open land
2. Forest land
3. Fresh and salt water wetlands
4. Mining and waste disposal areas
5. Urban lands
6. Outdoor recreation facilities

d. Transfer this information to USGS maps at 1:24,000 scale (1" = 2000 feet) adding new roads and other important new map information.

e. Print 200 copies of each map for interested state and federal agencies.

f. Consolidate the 104 land-use and vegetative cover types into 28 broader types and construct new maps at 1:63,360 scale (1" = 1 mile) showing these types. The minimum typing size will be 20 acres. Mining and waste disposal areas as well as outdoor recreation will be located by points on these maps.

g. Establish a data bank in computer form and manipulate the map information to bring to light changes and trends in the extent, character and location of the more interesting types.

h. Prepare statistical summaries of this information by towns, counties and for the state.

i. Compare the situation on maps and in area statistics generated from 1951-1952 photographs with the new maps and statistics generated from 1971-1972 aerial photographs in this project.

j. Make predictions of future changes based on past changes, population shifts, highway construction and other factors.

k. Analyze and interpret changes in land-use and vegetative types as they are related to demographic, socio-economic, and ecological factors. This work will involve several co-investigators from various departments who have worked with us on a wetlands project.

l. Use the type maps as ground truth for the ERTS/EROS imagery.

m. Train photo interpreters to use satellite imagery to monitor the environment on a short-term basis.

n. Employ computer techniques for storing, retrieving and manipulating environmental information revealed on satellite imagery using the LUIS computer map system developed here.

Massachusetts Map Down is an ongoing multidisciplinary land-use and vegetation mapping program which has been in existence in the Department of Forestry and Wildlife Management for over 20 years. The entire state was mapped from 1951 and 1952 aerial photography by a system which was unique at that time. This work is being repeated using similar aerial photography taken in 1971 and 1972. This manual explains the Map Down land-use and vegetation classification system by defining the 204 land-use and vegetative cover types used to classify the lands for the Map Down maps. This manual is essential for interpreting the maps which show land-use and vegetation types overlaid on standard U. S. Geological Survey quadrangle maps at a scale of 1" = 2000 feet (1:24,000). The sample map shown in Figure 1 is a reduced copy of a Map Down map. The maps are available at 1:24,000 scale; Figure 1 is at 1:62,360 scale (1" = 1 mile).

Maps for the 1951-1952 time period and those from the 1971-1972 time period are available. Area statistics and analysis of land-use changes by towns from 1951 to 1971 are available from the Cooperative Extension Service, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, Massachusetts, 01002 for $1.00 per county. Barnstable, Dukes and Nantucket Counties are available under one cover for $1.00 and Suffolk and Norfolk Counties are also under one cover.

THE CLASSIFICATION SYSTEM

The classification system was made for use in southern New England and uses descriptive land-use terms common to that part of the country. Since each type is a homogeneous land-use unit, the types are comparable and therefore interchangeable with land-use types used in other systems. With the addition of a few more types the system would be applicable to all New England and New York.

The classification system was devised to describe the nature of the land itself, the vegetation on the landscape, or the land use. The system includes only features that can be consistently and accurately interpreted on 1:20,000 scale panchromatic photographs taken when vegetation is in leaf. The classification system has six categories which are described below. The minimum sized typing unit is determined by the map manuscript scale and that size is three acres.

Agricultural and Open Lands - 11 Types

One way to classify agricultural and open land is by the vegetation which it supports. To a degree, vegetative cover defines the land value, its aesthet quality, its value for wildlife, and its potential for other uses. Vegetative cover, land use and the nature of the land itself are the basis of all the land classifications in this study.

T - is tilled or tillable crop land which is or has recently been intensively farmed. The boundaries on the ground are usually sharply defined and well maintained because the land is valuable. The land supporting farm buildings is included as part of this type.

TU - is unused tillable land which has not recently been tilled and is not part of an agricultural unit. This kind of land occurs near growing urban areas and it is usually mowed annually to maintain its value.

P - is pasture or wild hay land which is not suitable for tillage due to steepness of slope, poor drainage, stoniness, or lack of fertility. This land has less sharply defined boundaries and often has occasional scattered shade trees for the grazing animals.

AF - is abandoned field which is reverting to wild land. Woody vegetation and grass are abundant but tree crown cover is less than 30%. If the tree crown cover were greater than 30%, the land would be classified as forest. This land is highly productive of wildlife. Most of this land was pasture or wild hay land before abandonment.

O - is productive fruit orchard.

AO - is abandoned orchard. In addition to the decadent fruit trees, grass and woody vegetation are abundant in this type.

CB - is productive cranberry bog. Abandoned cranberry bog soon succeeds to a wetland type usually becoming shrub swamp (SS).

N - is land supporting nurseries. This type would include greenhouses and land adjacent to them as well as lands supporting horticultural specialties, ornamentals, shrubs and Christmas trees.

H - is the heath plant community as well as grass, shrubs, and other low vegetation found on poor sandy soils on Cape Cod and the adjacent islands.

S - is open sand areas which may support scattered herbaceous vegetation. Sandy beaches are a separate outdoor recreation type.

PL - is powerlines or buried telephone lines, gas or oil pipe lines or other right-of-way 100 feet or more in width maintained through wooded areas. Where powerlines cross agricultural or wetland and require no maintenance they are typed as the vegetative type or the land use permitted under them.

The 11 agricultural or open land types are grouped into five types for coloring on 1:24,000 scale maps. These five types will be used on maps made at a later date at a scale of 1:63,360 (1" = 1 mile) and the grouped types will use the symbols shown below. Next to the grouped types in parenthesis is the symbol for the types in the group and next to that is the wax-based Eagle Prismacolor or Castell color pencil used to color the type group. Since there are 28 type groups, careful selection of colors must be made in order for the eye to detect differences between them.

EA - Extensive Agriculture (P) Eagle 918
IA - Intensive Agriculture (T, TU) Eagle 941
WA - Woody Perennials (O, N. CB) Eagle 923
O - Open Areas (AF, AO, PL, S) Eagle 917
H - Heath (H) Castell 134

Forest Lands - 40 Types

Forested land is classified by a system which describes the forest by species, height and density. Species differentiation is necessary because some species have greater value for wood products, for wildlife habitat, or have a greater resistance to recreational impact than do others. Height indicates tree size, while density determines light conditions under the stand and the likelihood of lesser vegetation growing under it. Species height and density together help to determine the visual quality of the forest. Tree species groups are designated by letters as follows:

S - softwoods constitute at least 80 percent of the stand.
H - hardwoods constitute at least 80 percent of the stand.
HS - a mixture of hardwoods and softwoods with hardwoods predominating.
SH - a mixture of softwoods and hardwoods with softwoods predominating.
P - forest plantations are indicated by prefixing the symbol P to the forest type symbol.

Tree height classes are designated by the numbers 1 through 6.

1. 1 ft. - 20 ft.
2. 21 ft. - 40 ft.
3. 41 ft. - 60 ft.
4. 61 ft. - 80 ft.
5. 81 ft. -100 ft.
6. Uneven heights (three or more height classes represented)

The density classes are designated by letters.

A. High density, 81 to 100 percent crown closure.
B. Low density, 30 to 80 percent crown closure.

Density classes are not applied to 1 and 6 height class trees because it is difficult to interpret and not meaningful. This code method of classifying or typing forest stands lists species, height, and then density as in the following examples:

H2A is a hardwood stand 21 to 40 feet in height with high density.
HS5A is a mixture of hardwoods and softwoods with hardwoods predominating. The stand is 81 to 100 feet tall with high density.

The 40 forest types are grouped into seven types for coloring on 1:24,000 scale maps. These seven types will also be used on maps made at a scale of 1:63,360 (1" = 1 mile) and the following group type symbols will be used:

SSF - small softwood forest (S) 1, 2 and 6 heights Castell 161
LSF - larger softwood forest (S) 3, 4 and 5 heights Castell 155
SMF - small mixed wood forest (SH and HS) 1, 2 and 6 heights Castell 167
LMF - larger mixed wood forest (SH and HS) 3, 4 and 5 heights Eagle 911
SHF - small hardwood forest (H) 1, 2 and 6 heights Eagle 913
LHF - larger hardwood forest (H) 3, 4 and 5 heights Eagle 910
PF - plantation forest (P) all plantations Eagle 944

Wetlands - 11 Types

The wetland classification is a modification of that used by the Office of River Basins of the U. S. Fish and Wildlife Service. That classification was simplified so that wetland separation could be accurately made on the 1:20,000 scale aerial photographs used in the study. Wooded swamps may be located by forest type symbols over the swamp symbols shown on the underlying U.S.F.S. map. Areas of wooded swamps are not kept separate from other forested areas in this study. The swamp situation on the U.S.G.S. maps is not verified by photo interpretation since wooded swamps cannot be interpreted on "leaves on" 1:20,000 scale air photos. They can be interpreted on 1:12,000 or larger scale "leaves off" spring photography.

SF - is seasonally flooded basins or flats. This type occurs principally on stream floodplains and the most common plants are grasses and herbaceous species. The soil is waterlogged or covered with water during spring freshets, but well-drained during the growing season. This type is difficult to recognize on summer aerial photographs because it does not support a distinctive vegetation complex.

B - is bog. The typically acid, peaty soil is waterlogged and supports a distinctive plant community which usually includes most of the following: heath shrubs, cranberries, pitcher plants and sedges. Scattered black spruce, tamarack and red maple may be present. A mat of sphagnum moss is the most characteristic feature of bogs.

SS - is shrub swamp. The soil is waterlogged during the growing season and is often covered with as much as six inches of water. Common woody species are alder, buttonbush, dogwood and willow. Sedges are usually present in tussocks.

M - is meadow. The soil is waterlogged through most of the growing season and surface water is present only for a short period during the spring. Vegetation is predominantly grasses, rushes and sedges. Rushes, which grow in the wetter parts of many meadows, photograph very darkly making this type easy to identify.

SM - is shallow marsh. This type is wetter tham meadow. The soil is completely waterlogged and often covered with up to six inches of water during the growing season. There is usually some open water and the predominant vegetation is emergent, including such plants as cattails, bulrushes, burreed, pickerelweed and arrowhead with some grasses and sedges present.

DM - is deep marsh. Water depth ranges from six inches to three feet. Fairly large open water areas are bordered by, or interspersed with, emergent vegetation like that found in shallow marsh. Floating and submergent plants such as water lilies, duckweed, watershield and pondweeds are also present.

W - is open water in lakes, rivers and large streams. Water depth is greater than three feet during the growing season. The boundary of coastal water is located by drawing a line at the river mouth to connect the edges of the coastline, or man-made features like roads, railroads or bridges crossing rivers or inlets are used to establish it.

BP - is beaver pond. These ponds resemble one or more of the above types but they owe their origin to beaver.

TSM - is tidal salt marsh which is flooded twice daily. Vegetation is primarily saltmarsh cordgrass.

ISM - is irregularly flooded salt meadows, flooded at monthly high tides and during severe storms. Vegetation is primarily saltmeadow cordgrass, saltgrass and black rush.

DSM - is ditched salt meadow which has been ditched for mosquito control or for agricultural purposes. Vegetation is the same as ISM.

The 11 wetland types are grouped into four types for coloring on 1:24,000 scale maps. These four types will be used on 1:63,360 scale maps employing the following group type symbols:

W - open freshwater (W) Eagle 919
FW - shallow freshwater wetland (SS, M, SM, SF) Eagle 920
DW - deeper freshwater wetland (DM, B, BP) Eagle 906
SW - saltwater wetland (TSM, ISM, DSM) Eagle 933

Mining or Waste Disposal Areas - 5 Types

Mining in Massachusetts is mainly for sand, gravel or stone. Waste disposal areas occupy much space and they usually have unsightly characteristics.

SG - Sand or Gravel - This land is used for the extraction of sand or gravel.

OM - Other Mining - This land is used for the extraction of stone and material other than sand or gravel. Mining sites, though ugly to most, are fascinating to rock collectors.

D - Dump - This land is used for dumping waste and refuse materials such as tin cans. Active sanitary land fills would fall into this class. Once revegetated, these lands fall into one of the other land-use categories.

DA - Automobile Dumps - Automobile graveyards or active automobile junk yards.

FB - Filter Bed - This is land and associated buildings used for treating liquids containing organic or chemical matter.

The five mining and waste disposal types are grouped into two types for coloring on 1:24,000 scale maps and the following group symbols will be used on 1:63,360 scale maps:

M - Mining land (SG, OM) Eagle 914
WD - Waste disposal (D, DA, FB) Eagle 948

Urban Land - 22 Types

Land classified as urban for the most part encompasses a large number of people living and working in closely ordered structures in a confined land space. Urban limits are at the border of the block street pattern or just beyond it. Each urban type includes the access roads, parking facilities and other features which go with the complex. Industrial, commercial, residential and transportation lands make up the urban type.

UI - is heavy industrial land containing facilities for the manufacture, storage and assembly of raw or partially processed products such as machinery, metals, chemicals, petroleum, or electrical power. Such industries often have large smokestacks and large storage areas. Warehouses and transportation facilities for bulk products and an open and interrupted street pattern characterize this type. Air and water pollution as well as unsightliness are often characteristics of heavy industry.

UL - is light industrial land containing facilities for the manufacture or assembly of smaller, partially processed products such as electronics, appliances, and other secondary process products. Large smokestacks or raw material storage facilities are never present, air and water pollution are seldom a problem, and light industries are not apt to be unsightly. Many modern light industries are well landscaped and are indistinguishable from commercial activity on aerial photographs.

UC - is commercial land predominantly used for distribution, or merchandizing goods and services. Stores, hotels, offices, parking garages, apartment buildings and smaller warehouses are usually set close to streets having a close pattern. Trees are rare in downtown commercial areas. Most of the city people not living in residential areas live here. This type includes modern, landscaped commercial buildings away from the urban core.

UH - is highway commercial land used for merchandizing goods and services to the traveling public away from urban centers. Gas stations, motels, restaurants, drive-ins and stores located in strips along major routes of travel make up this type.

US - is shopping centers away from the urban core which are surrounded by large parking lots and may have some landscaping and trees as part of the complex. Theatres are often located in shopping centers to take advantage of the parking.

UP - is public or quasi-public land with "grounds" and green space which contains facilities to serve large numbers of people. Examples are: schools, colleges, churches, hospitals, state hospitals, prisons, etc. When located in the urban "core," public buildings without "grounds" cannot be identified on air photos and they would be classified UC.

UA - is "garden" apartments which are usually located outside the "core" city, are set back from the street, have some "grounds" and may have attached recreational facilities like swimming pools and tennis courts. Apartments without "grounds" in the "core" city are typed UC.

UT - is tenaments, town or row houses or apartment buildings set close to streets having a close pattern. They are for the most part three or more stories in height which helps distinguish them from URH, which are less than three stories tall. Some goods or services are sold here, but the area is predominantly used for high density urban living.

URH - is high density urban residential land used for homes which are spaced closely, set back from the street, and arranged in orderly rectangular patterns on lots less than 1/4 acre in size. Nearly all the street frontage for these building lots is in the vicinity of 50 feet and many of the streets are laid out at 200' intervals. There are about eight dwelling units per acre. These are usually located in older urban areas, or are cottages near the ocean, or are mobile home parks.

URM - is medium density residential land used for homes which are spaced closely and arranged in orderly curved or rectangular patterns and set back from the street on lots which are predominately 1/4 or 1/2 acre in size. Most of the street frontage is 100' in width and there are two to four dwelling units per acre.

URL - is light density residential land with lot sizes from 1/2 acre to one acre in size. Most of the lots are one acre in size and there is one dwelling unit per acre.

URO - is open, very light density residential land with large lots from one acre to two acres in size.

URF - is very light density, forested, residential land with large lots greater than one acre in size with forest cover. In this type only space for the house and a small lawn are cleared in the forest. More than 75% of the forest is left intact in this type where the lots are predominantly two acres in size.

UE - is estates three acres or more in size with extensive lawns, gardens, shrubs and other "grounds."

UCR - is clustered residential land with clusters of three to ten domestic dwellings in farming or forested areas.

UO - is open undeveloped land which is lying idle in the midst of urban areas or adjacent to them. Such land awaits an opportune time for development. This type includes land which has been cleared for urban development of an unknown kind.

UTA - is airports with landing strips, hangers, parking areas and related facilities. Small airfields without runways, hangers or other specialized facilities are not typed as airports.

UTW - is docks, warehouses and related land-based storage facilities for water transportation and commercial fishing. Liquid storage facilities like tank farms may be part of this type.

UTR - is railyards, terminal freight and storage facilities as well as rail stations for passengers. This type may include liquid storage facilities like tank farms.

UTT - is terminal freight and storage facilities for truck freight including liquid storage facilities. Bus terminals are included in this type. Transportation facilities which are part of an industrial complex are included as part of the industrial type.

HW - is divided highways with 200 feet or more of right-of-way width. Narrower roads show on U.S.G.S. maps, but do not have their right-of-way mapped or measured for area.

† - is cemeteries. The cross symbols for older cemeteries are already on the U.S.G.S. base map. New cemeteries are added to the map. The area of cemeteries greater than 3 acres in size is measured.

The twenty-two urban types are grouped into six types for coloring and the following group symbols will be used on 1:63,360 scale maps.

UI - Industrial land (UI, UL) Castell 127
UC - Commercial land (UC, UH, US) Eagle 922
URD - Dense, residential land (UA, UT, URH) Castell 183
URL - Low density residential land (URM, URL, URO, URF, UE, UCR) Eagle 916
UT - Transportation land (UTA, UTW, UTR, UTT, HW) Eagle 967
UO - Urban open (UO, UP, †) Eagle 908

Outdoor Recreational Facilities - 15 Types

Outdoor recreation types are either water based, mainly for participation, mainly for spectators, or are environmental in character. Each recreational type includes the recreational complex: access roads, parking facilities, buildings and other related facilities. State parks, state forests, or town forests are

typed as forest land since they have no distinguishing features on aerial photographs. Many of these, however, are shown on the U.S.G.S. base maps, but their area would be computed as forest in this study. Campgrounds were not typed because they could not always be located under forest canopies.

Water based recreation

RM - is marinas or boatyards.

RFB - is freshwater sandy beach. This type includes bathhouses, parking and related facilities.

RSB - is saltwater sandy beach. This type includes bathhouses, parking and related facilities.

RS - is swimming pools. The complex including bathhouses and parking facilities must be three acres or more in size to appear on the maps.

Participation recreation

RC - is tennis courts. The complex must be three acres or more in size to be mapped.

RG - is golf courses. This type includes the club house and associated recreation facilities. If tennis or swimming facilities at country clubs exceed three acres they will be typed as RC or RS; if not, these recreation facilities will be part of the RG type.

RD - is golf driving ranges, skeet shooting ranges, archery ranges, etc.

RPG - is playgrounds. Playgrounds have a conglomeration of many types of facilities which may include tennis courts, swimming pools and athletic fields. If, however, any of these are three acres or more in size, they are separated out.

RSK - is ski areas for alpine skiing or ski jumping. This includes ski trails with the wooded space between them as well as the base facilities and parking area. Cross-country skiing trails cannot be located on air photos.

Spectator recreation

RT - is race tracks for horses, dogs or cars.
RA - is athletic fields and stadiums.
RAP - is commercial amusement parks.
RFG - is fairgrounds for agricultural fairs.
RI - is drive-in theaters.

Environmental recreation

RP - is an urban park or "common" which is intensively used "green space" in the city. A zoo would fall in this class.

The 15 recreation types are grouped into four types for coloring and the following symbols will be used on 1:63,360 scale maps:

WR - Water based recreation (RM, RFB, RSB, RS) Eagle 929
PR - Participation recreation (RC, RG, RD, RPG, RSK) Eagle 932
SR - Spectator recreation (RT, RA, RAP, RFG, RI) Castell 130
ER - Environmental recreation (RP) Eagle 934