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# QUANTIFICATION OF THE ANTHROPOSYSTEM CONCEPT

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**ABSTRACT**

Recently the anthroposystem theory was postulated by this author in an attempt to describe any environmental system developed by man that can perpetuate itself. Modern science is based on quantification of theory, and indeed, precise numerical terms or measurements and scientific testing are almost inseparable. Only after a system is quantified can one mathematically predict the system's behavior. This paper identifies and quantifies the position or role in the environment that an anthroposystem occupies. The quantification of the anthroposystem is one of the most important aspects of the study of humans and their environment. With such knowledge, the design of a sustainable human system and an inter-related long-range life-support system can be undertaken.

## INTRODUCTION

In recent years the realization that man is depleting the planet's natural resources and polluting the environment has generated a strong interest in the study of human environments. Consequently, "environmental science" has emerged as a distinct discipline. The quest of this new science to study "all systems of air, land, water, energy, and life that surround man" [1] is so all-embracing that it seems to frustrate scientific analysis; yet the chief objective of any science is to search for facts and to correlate those facts with existing theories and laws. Because of its all-encompassing, cross-disciplinary objective, environmental science at present, to use Forrester's terminology, draws heavily on "written and numerical data-bases" [2] and has not yet formulated theories such as those existing in the most established sciences of physics, chemistry, and biology.





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Last year this writer proposed the mental model[1] of the anthroposystem as an interfacing functional unit produced by humans for the purpose of maintaining their civilization [4]. The anthroposystem is an intuitive testable model; thus, the concept provides a working plan that can be used to formulate other theories. A fundamental problem, however, is relating the model to reality. It is a gloomy thought that our environment may be so complex in space and time that a universal concept such as the anthroposystem must be either imaginary and/or unrealistic: To avoid the pitfalls of treating life-support systems as oversimplified black boxes scientists must develop universal theories that clarify, quantify, and unify sustainable human environment systems. That is, we must develop testable theories that explain and predict the behavior of the "forest" (the entire human-environment system) not just the trees.

## CONFIGURATION OF THE ANTHROPOSYSTEM

An anthroposystem is a restricted portion of the environment that forms a structural and functional unit of interwoven and overlapping hierarchies among the levels of organization that maintain civilization [4]. Logically, numerous functional and/or habitat resources affect an anthroposystem's ability to maintain itself in a particular environment. For example, let us imagine an island anthroposystem, which is perhaps the easiest anthroposystem to analyze because it has a clear geographical boundary. Let us suppose further, for sake of analysis, that our system requires only five factors: Temperature, oxygen, precipitation, chromium, and petroleum. For each factors, the anthroposystem will function most efficiently within a fixed range, as indicated in Figure 1. We can present the first two factors, temperature and oxygen, as the axes of a two-dimensional graph on which any single point represents a locality with a specific temperature and oxygen level. As seen in Figure 2, the shaded area of the graph indicates all the possible temperature-oxygen levels within which the anthroposystem can maintain its integrity, or its structure and function.

We can add a third, fourth, and fifth axes representing precipitation, chromium, and petroleum requirements. The optimum levels pass through the origin (0, 0) of the cartesian coordinates, thus deliniating a 5-axes space, and indicating tolerable combinations of the five variables. The two-dimensional area that results is a geometric representation of that anthroposystem's configuration (Figure 3).

Each given factor can also be visualized as one coordinate in an infinite-dimensional space with upper and lower limits for the maintenance of the integrity indicated. The many dimensions of this "hypervolume" represent

[1] Dr. Peccei, founder and guiding father of the Club of Rome, defined mental models as "models that the human brain employs to judge situations, prospects and actions." [3]

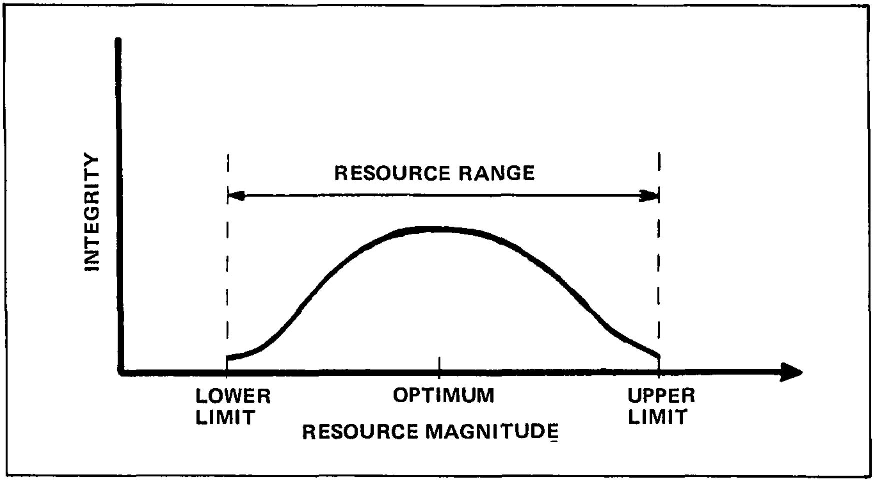


Figure 1. Effects of resource magnitude on an anthroposystem's integrity. Integrity, the maintenance of the structured and functional characteristics of the anthroposystem declines as availability of any factor deviates from optimum level. This occurs as a result of the accumulation of pollutants and/or because of the law of diminishing returns. Generally, the integrity is affected by pollution and the unintended by-products of industrialization rather than by the depletion of resources [5, 6]. Habitat factors (e.g., temperature) also have their minimum, optimum, and maximum levels.

environmental parameters, on which one conceptually plots the anthroposystem's limits. The hypervolume concept has become popular in describing an ecological niche for a species [7]. By analogy one can state that an anthroposystem's configuration and hypervolume represent that system's environmental niche.

The quantification of an anthroposystem's configuration (and hypervolume) aids in understanding its environmental stability. The simplest method of expressing a system's stability is in a geometric index such as presented in Figure 4. One of the basic problems with using a geometric index is the determination of the relationship between the magnitude of resource ranges and their positions on the absolute scale of the cartesian coordinate. Also, interactions among the factors almost always occur and this would alter the configuration of the system. Thus an actual geometric stability index will have to await the completion of monographic research.

Another index of stability could be based on the importance of each factor. That is, not all factors are equally important in maintaining the integrity of an anthroposystem. Of the many factors required by a system, relatively few exert a controlling influence by virtue of their qualitative and quantitative roles.

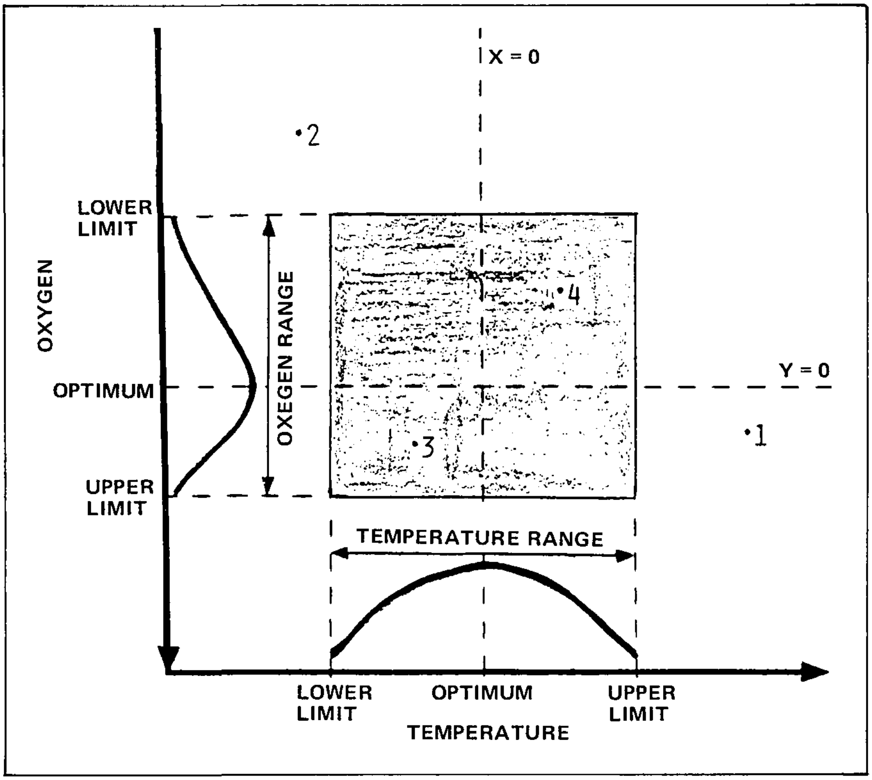


Figure 2. Two-dimensions of the configuration of an anthroposystem. Any anthroposystem's integrity is restricted to a range of temperature and oxygen levels. Each point in the shaded area represents a possible environment, a combination of temperature and oxygen levels. If a given area in the universe presents only environments in which the temperature-oxygen levels fall outside the shaded area as do points 1 and 2, no proposed anthroposystem located there could maintain its integrity.

For example, the lack of petroleum of a petroleum-base industrialized society would create an immediate economic and political crisis. Whereas, a society that has its energy demands distributed among various resources is less vulnerable and more stable. The degree of necessity of a specific factor to the maintenance of a system's integrity can, therefore, be expressed by an appropriate index of importance that sums up each factor's relative value in relation to the anthroposystem as a whole.

If we list the resource requirements and their relative importance in two difference anthroposystems (which we will designate as A and b), we can calculate the stability of these systems :

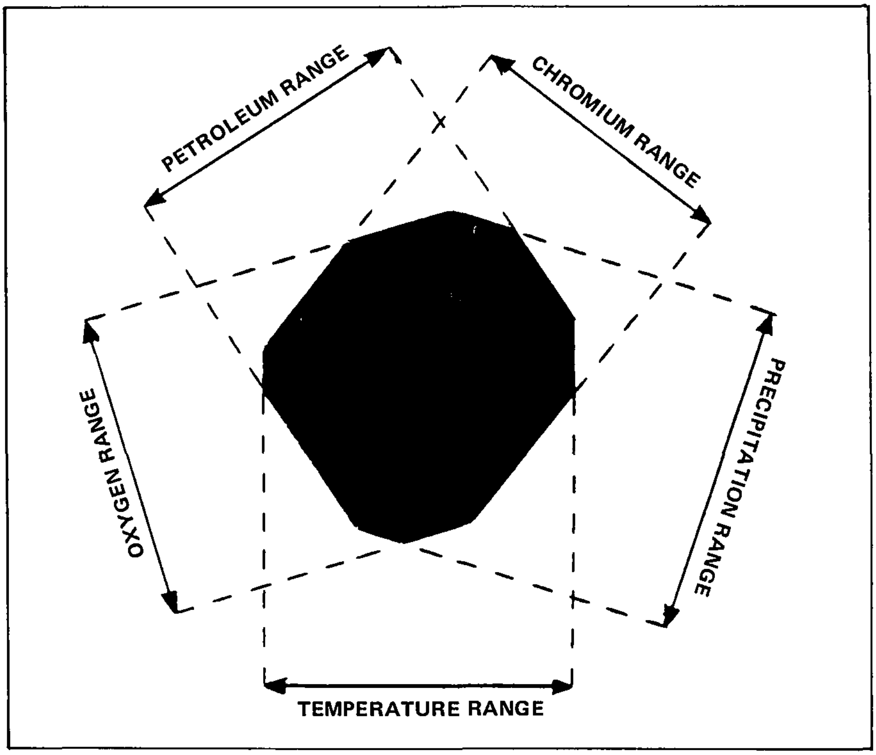


Figure 3. Two-dimensional configuration diagram for an anthroposystem requiring only five factors. The configuration is represented by the perimeter (solid) lines. If a space contains combinations of the five variables that lie within the range indicated by the shaded area, an anthroposystem at that location could maintain its integrity. For illustrative convenience the five axes meet at the 0.0 coordinate.

| | *Relative Importance of Resources* | |
|---|---|---|
| *Factors* | *Anthroposystem A* | *Anthroposystem B* |
| Temperature | 2 | 1 |
| Oxygen | 2 | 1 |
| Precipitation | 2 | 1 |
| Chromium | 1 | 1 |
| Petroleum | 3 | 6 |

From this list it is obvious that petroleum is more important to system B than A. A simple index of stability based on importance (Si) may be calculated as follows:

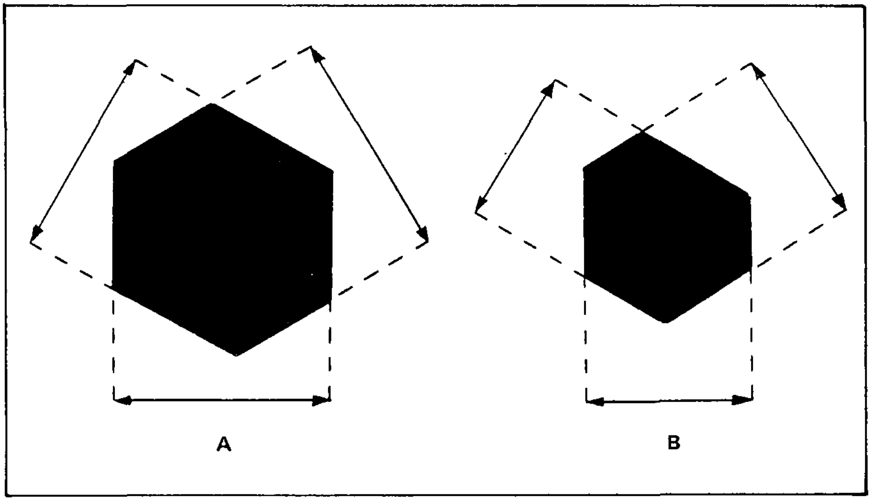


Figure 4. The shaded area that represents an anthroposystem serves as a numerical measure of the limits within which that anthroposystem can function. It is intuitively obvious that, for given factors, a system with a greater magnitude and thus greater geometric area (diagram A) will be more stable than one with a smaller magnitude (diagram B). The former will have a greater ability to maintain its overall integrity in the face of changing factors.

$$Si = 100\,(P \text{ of } X^2)$$

where P is the probability for a given $X^2$ value. If expected is the evenness of equal importance of all factors ($E = \frac{10}{5} = 2$), than $X^2$ value for system A is:

$$X^2 = \frac{(\text{observed-expected})^2}{\text{expected}} = 1$$

The calculated $X^2$ value of 1 is compared to tabled values for corresponding number of degrees of freedom (df = 4) to obtain the probability level ( p = 0.9). Substituting:

$$Si = 100(0.9) = 90.0$$

Thus, for anthroposystem A, the stability based on importance of each factor equals 90; for anthroposystem B, $X^2$ = 12, P = 0.02, and Si = 2. Consequently, system A would be more stable than system B. (A system which relies equally on all its resources would be more stable than a system that relies heavily on one particular resource).

The geometric and importance indices can be viewed as examples of the so-called "non-oscillation stability" or "stability resilience." [8] Stability is essentially a function of the complexity of the recycling of matter and/or of energy flow, in which a large number of interacting pathways provide mechanisms for the adjustment to stress.

In assessing an anthroposystem's stability, by either of the above methods, we are describing its survival ability in terms of its predictable surroundings or environment. However, a complete description of an anthroposystem's total configuration would have to include other criteria, such as the possibilities of catastrophic events (e.g., earthquakes), as well as political and economic factors. Probabilistic predictions of natural catastrophes can be made and are based on recurrence periods for rare events [9, 10]. Political and economic systems are goal oriented, and thus no assessment of their affect on the anthroposystem's configuration can be completely free of social influences. Or as Gerlach and Hine write "(H)uman systems. . . are different qualitatively from animal organic systems in their capacity for self-awareness, symbolization, and rational thought." [11] Social systems, however, function within environmental systems [12]. No social system, for example, can go against the second law of thermodynamics. As Clapham writes:

> A democratic society can choose how to manage its landscape, but it cannot determine the environmental principles that govern the responses of the landscape to that management. Nor can it choose how others manage theirs. For example, we can choose to have wilderness or to cut virgin trees, but we cannot choose that soil will not erode once the trees are cut. We can choose to have cities that dump toxic wastes into rivers and estuaries, but we cannot choose to have salmon still swim through the polluted water to reproduce. . . . [13].

Historians are beginning to appreciate the importance of resources to civilizations. Recent evidence suggests that the rise and fall of civilizations can be largely attributed to environmental factors [14-16]. As restated by Watt, the decline of many civilizations can largely be explained "in terms of the intensity of pressure by the civilization on the resource base that supports it," and by the attitudes of the inhabitants toward "the importance of wise management of the resource base, so as to make it last over the long term." [17] Thus ecological forces are more important in regulating past, present, and future history than one would expect. This "surprising" behavior of natural systems has been labeled "counterintuitive." [18]

## THE ANTHROPOSYSTEM AND SYSTEM SYNTHESIS

According to Bennett and Chorley, system synthesis tries to develop a conceptual model "as close as possible to the structure of the real world." [19] Thus an anthroposystem is ideal for system synthesis. The four components of an anthroposystem (producer, consumer, decomposer, and matrix) represent subsystems of a sustainable human system (Figure 5.). These parameters are assumed to be linked and their functions are known and predictable [4].

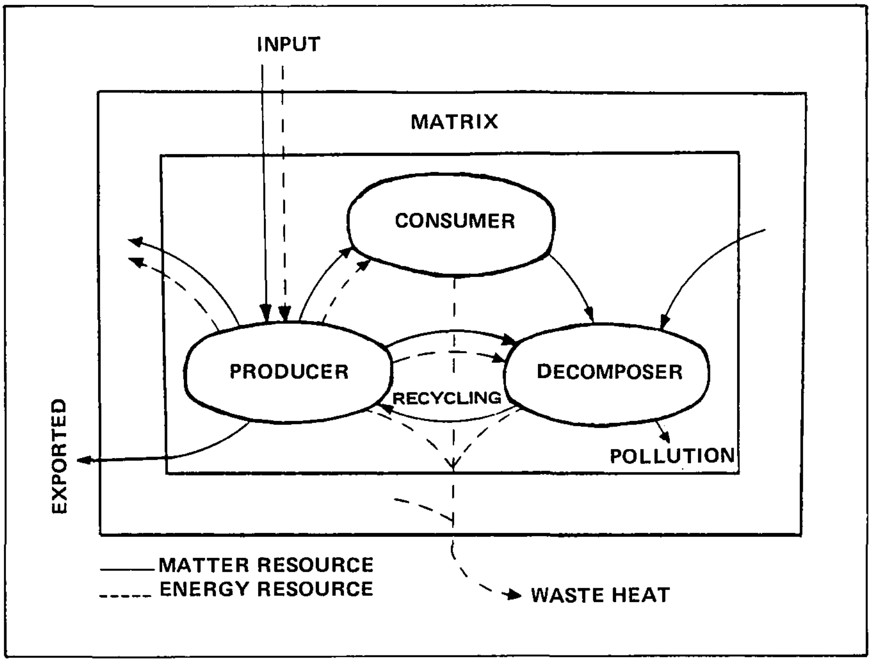


Figure 5. An anthroposystem can be visualized as a synthesis of sustainable human systems that can be represented as a complex of feedforward cascades of energy flow and matter cycling between the four components (producer, consumer, decomposer and matrix). Input refers to the amount of energy or matter introduced into the system for storage, conversion of kind, or conversion of characteristics.

An anthroposystem can be defined by a set of coupled differential equations, one for each of the four components (i.e., dynamic state variables-X), expressed in terms of matter cycling/energy flow between the components (i.e., non-dynamic state variables -F):

$$X_1 = F(X_1, X_2, X_3, X_4, t)$$

where the function maps the 1-space where elements are at time t, and the real n-space or vector space where elements are vectors X [20]. The equations for matter cycling are provided in Figure 6.

## CONCLUSIONS

The description of an anthroposystem is one of the most important aspects of the study of humans and their environment, because it is from such knowledge that understanding of a sustainable human environment system can be obtained.

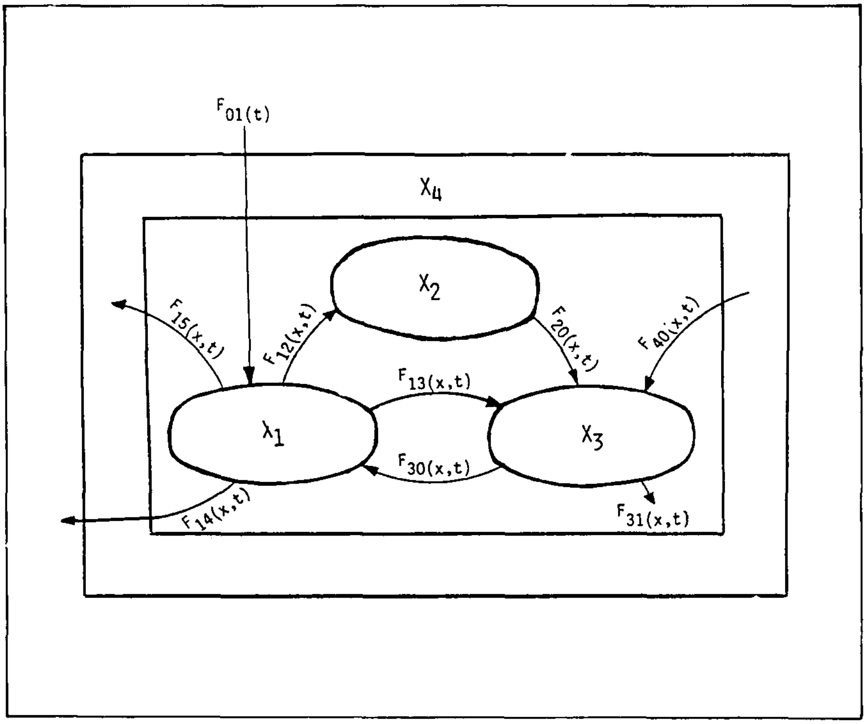


Figure 6. Cycling of matter through an anthroposystem.
$X_1$, $X_2$, $X_3$, and $X_4$ = Anthroposystem components
$F_{ij}$ = Rate of cycling of matter from i to j
$X_i$ = Concentration of matter in the donor component
$X_j$ = Concentration of matter in the recipient component

$$\frac{dX_1}{dt} = F_{01} + F_{30} - F_{12} - F_{13} - F_{14} - F_{15}$$

$$\frac{dX_2}{dt} = F_{12} - F_{20}$$

$$\frac{dX_3}{dt} = F_{20} + F_{13} + F_{40} - F_{30} - F_{31}$$

$$\frac{dX_4}{dt} \equiv F_{15} - F_{40}$$

The quantification of the configuration (geometric and importance indices) of an anthroposystem is an attempt to construct a realistic and testable universal model. A system that fits this model, exactly, would be an ideal anthroposystem. Real anthroposystems deviate from the ideal in varying degrees and the deviation itself is quantifiable. One can postulate a model of an ideal sustainable anthroposystem, obtain an equation of state, and compare it with the empirical equation of state which describes the real system. Such a comparison provides an index of how sustainable real systems are. One might compare the anthroposystem concept to the ideal gas law. No gas behaves precisely in accordance with Boyle's and Charle's Laws [21], yet these laws are of practical value.

The anthroposystem quantification is necessary for the development of a long-range perspective from which scientists can analyze, quantify, and develop environmental knowledge regarding life-support systems in space and time. This should not be interpreted to mean that all scientific models must be quantifiable. The theories of the atom and evolution are principles without adequate mathematical models, yet, they are among the most profound concepts that help us in understanding ourselves and our universe. As the late population ecologist R. H. MacArthur so adequately expressed it: "A theory must eventually be falsifiable to be useful to a scientist, but it does not in itself have to be directly and easily verified by measurement. More often it is the consequences of the theory that are verified or proved false." [22]

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