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FOOD SYSTEMS AND SOCIETY–THE SYSTEMS EVOLUTION

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ABSTRACT

'Food Systems and Society' implies a system in which society is composed primarily of food producing and non-food producing sectors. Both the sectors converge and give rise to food consuming and non-food consuming populations–a systems mix in any particular natural environment. These sectors together form the main objective of the present study in relation to the total food environment.

A *food system* can be defined as a subset of the 'natural' system with a total set of social relations. The major theme is the evolution of the structural properties of the whole system as well as their time evolution with linkages to various other systems and subsystems that become involved. The present treatment traces the philosophical evolution of food systems and society with reference to boundary conditions that are changing and unfolding the unstable and stable conditions of the system.

The heuristic model proposed, describes the state of vulnerability of a society to famine conditions and suggests that an intra-equilibrium achieved by Geosystem, Ecosystem, and Socioeconomic System in the *systems mix* for any society, would apportion the character of non-vulnerability to famine. The interplay of major economic activity components like income, production and consumption tend to define in this case the heuristic equilibrium field in a

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congruent physical environment, thus bringing into fore the intervention required to restore a famine state into a state of non-vulnerability.

INTRODUCTION

Any approach to systems analysis involving natural resources has to be traced back to the fundamental system of the earth—that is the geosystem (see Figure 1). Through the interaction of natural ecology and the geosystem we arrive at the

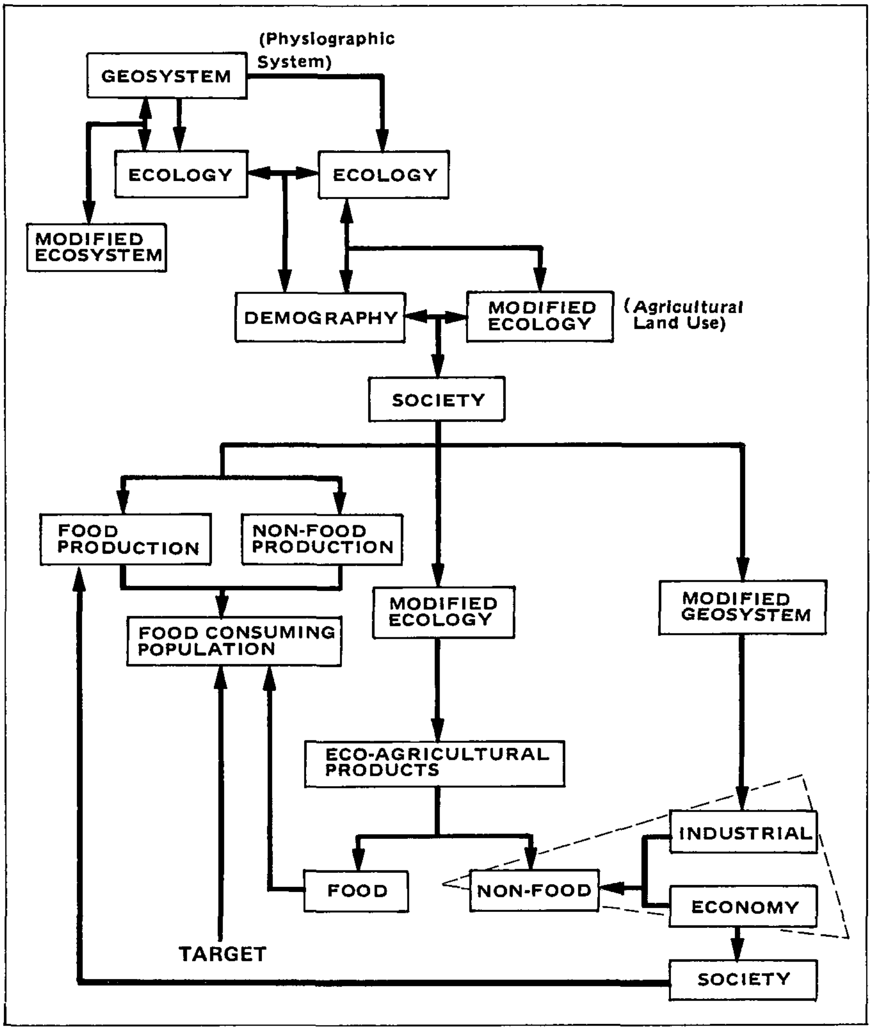

Figure 1. Systems evolution of food systems and society.

modified ecosystem. On the other hand natural ecology and human ecology combine to give a demographic pattern. Demography again interacts with human ecology and gives rise to modified ecology where agricultural land use is initiated. Modified ecology and demography, by interacting with each other, form the society in which we live. The society therefore has four components in the system, viz., food production, non-food production, modified ecology, and modified geosystem. The food and non-food production is related to the food consuming population. Modified ecology is forward linked to eco-agricultural products—which again has a forward linkage with food and non-food. The modified geosystem has a forward linkage with industry and non-food products, and both non-food and industry interact giving rise to an economy which can be traced back to the parental society. The component of food from the eco-agricultural products, on the other hand, is related to the food consuming population; and the food system and society has this main target of involving the food consuming population.

It is suggested that the systems approach to this case should entail three subsystems namely:

1. Physiographic-Ecological Subsystem
2. Socioeconomic Subsystem
3. Health-Nutrition Subsystem

and the linkages thereof. An index of vulnerability as the main objective of the systems approach is visualized here. It is argued that such vulnerability exposing segments of the population to acute distress conditions, even at the slightest fluctuation of food production caused by drought or flood, is a consequence of an essentially multifaceted structure of determination involving a large number of variables—physiographic, ecological, technological, socioeconomic, and cultural.

Our aim is here to discover the linkages between the major three subsystems as an associative phenomenon, a dependent phenomenon, and a causal phenomenon.

The model structure envisaged with feedback is shown in Figure 2. The data base oriented method for systems modelling in this case would therefore follow the diagram given in Figure 3.

Constraints to the development of such an operational system will vary from environment to environment; a term used to encompass political, social, economic, climatic and physiographic environments. It is important, however, to recognize that such environments vary over land surfaces and provide complex interrelated and interacting restraints to the efficient operation of any system proposed or developed. Their characteristics will also vary temporally.

To determine what is necessary to establish an efficient system the land area environments should be located within such a multi-dimensional restraint matrix. Through this, we shall be able to identify the problems that must be solved in

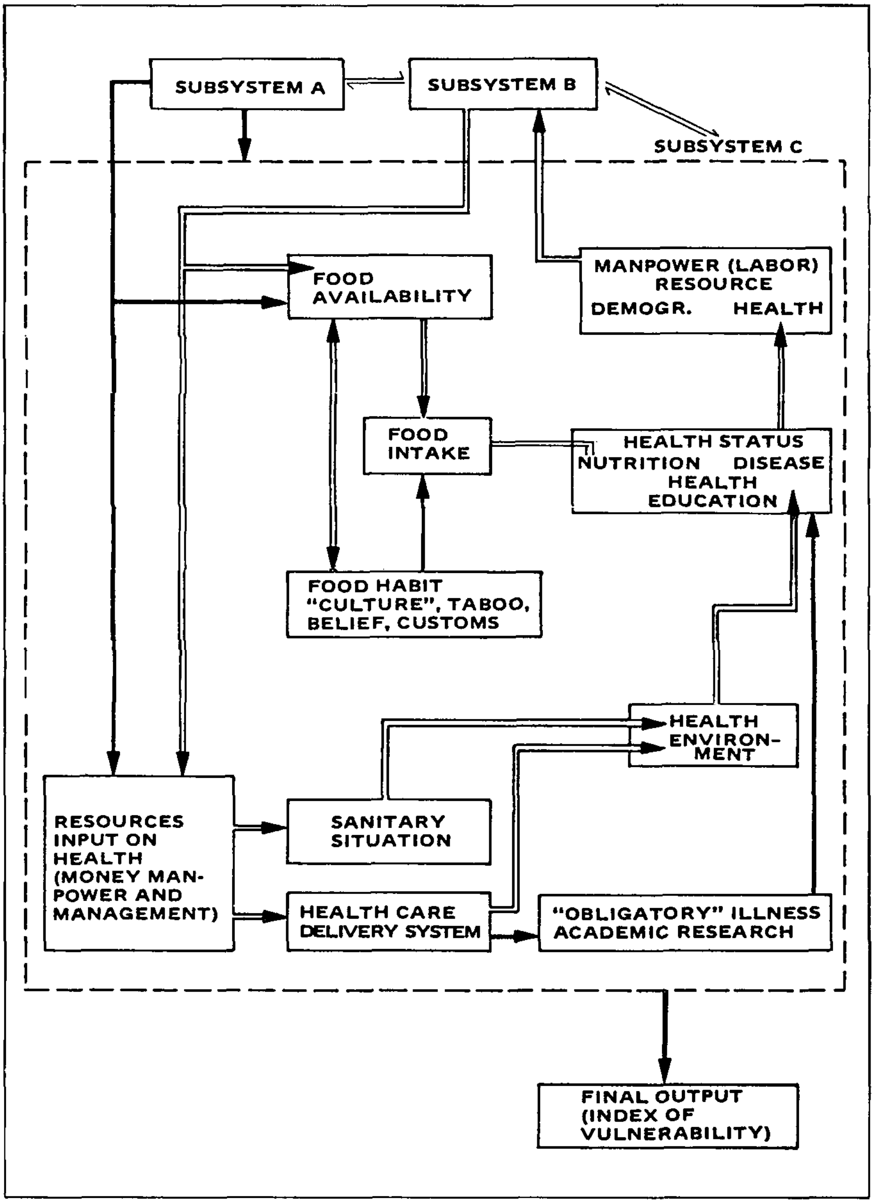

Figure 2. The model structure of the food systems and society with feed back loops involving the three Subsystems
Subsystem A—Physiographic-Ecological Subsystem,
Subsystem B—Socioeconomic Subsystem, and
Subsystem C—Health-Nutrition Subsystem.

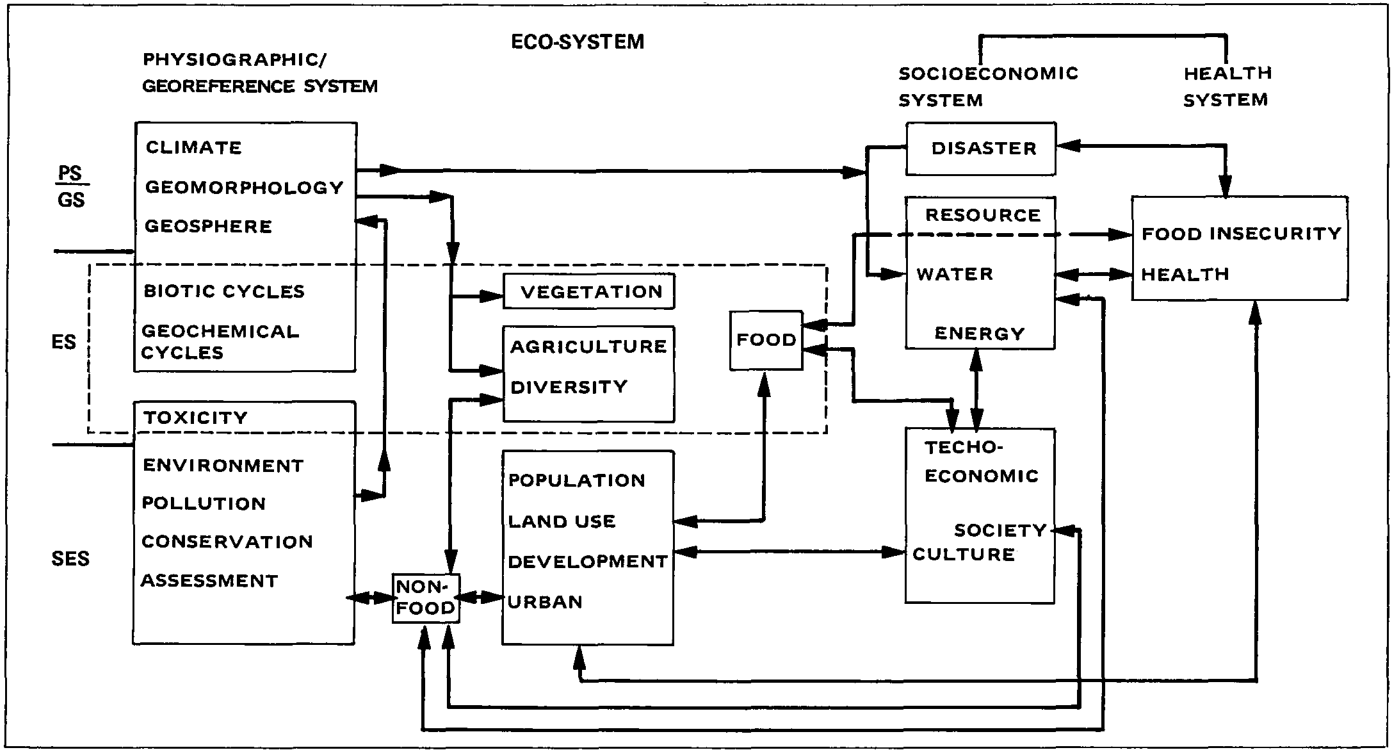

Figure 3. The data base orientation and their linkages in the systems model envisaged for food systems and society in its totality.

each environment if its requirements are to be met and if the data provided by the system are to be used. However, the interconnection of the components of each environmental complex makes the identification of logically reached conclusions very difficult to achieve. Therefore the land areas have to be examined and classified geographically and geologically.

From such spatially defined physiographic subdivisions along with data derived from climatic and meteorological systems, it therefore becomes possible to see how, for example, crop yields and floods may be predicted and therefore such units constitute the most appropriate geo-referencing framework for a systems program in food systems. Accepting the geo-referencing framework as the base of a systems approach to food systems and society, we potentially come to an area of great difficulty concerned with interfacing natural systems on the one hand (physio-ecological) and human systems on the other (socioeconomic and health). The former are believed to be structured in a manner that causes them to be dominated by stable negative feedback loops and by homeostatic considerations relating to energy flow, food chains, etc. They are much more vulnerable to change, observable only in the long run, and much more imbued with thresholds which once passed may not be retraced. Whereas socioeconomic and health systems are extremely flexible, potentially sensitive to unstable positive feedback loops (or at least to negative feedback loops which encourage explosive growth), but they nevertheless need to be protected against destruction by the flexibility of their structure and by the feedback mechanisms operated by human control. However, an explosive growth is no more the prerogative of positive feedback systems than homeostasis is of negative feedback ones. Indeed the structure of both types of systems heretofore referred provides an overall unification of systems operation which makes any simple division into the stable negative feedback physio-ecological systems and the unstable positive feedback of socioeconomical health systems very difficult to sustain. This gives rise to the two views of systems interfacing—the intervention view and that of symbiosis. In food systems and society, the intervention view may be said to define the boundary conditions while the "symbiosis view" is operational through all the subsystems involved: *physiographic, ecologic, socioeconomic* and *health*, and symbiosis preserves the stability of each subsystem.

Symbiosis, by definition, requires a "total systems" or "holistic approach" in which adjustment is extreme in time and space. Therefore in the whole food systems and society symbiosis, interdependence is represented not as an end point of social evolution, but as its inevitable ingredient. The dialectic of this process implies no necessary development sequence but a continuous evolution to maintain and stabilize (that is, to bring to a state of equilibrium) symbiotic regimes. And, design synthesis is the probable approach which permits the defects in systems evolution models of food systems and society to be overcome by symbiotic adaptation. These allow feedback and feedforward elements plus the ability to adjust overall goals, set up new sensors and information systems, and modify and extend their modes of coupling with the environment and with other societal systems. The form attempts to set up mathematical models of the non-environment interface to allow investigation, simulation and learning of the effects of societal networks on environmental feedback structure and vice-versa. It requires the development of highly complex monitoring and information systems which act as sensors and effector functions to sufficiently varied responses. These systems are composed of the five recursive subsets of actions: *observing, storing, processing, planning, implementing* and *administering.*

Such an integrated system for food systems and society has been attempted here and the structure is presented with positive and negative feedback loops (Figure 4). This will, by itself, indicate and lay down guidelines for resource allocation and is an approach to evaluation and monitoring of interventions.

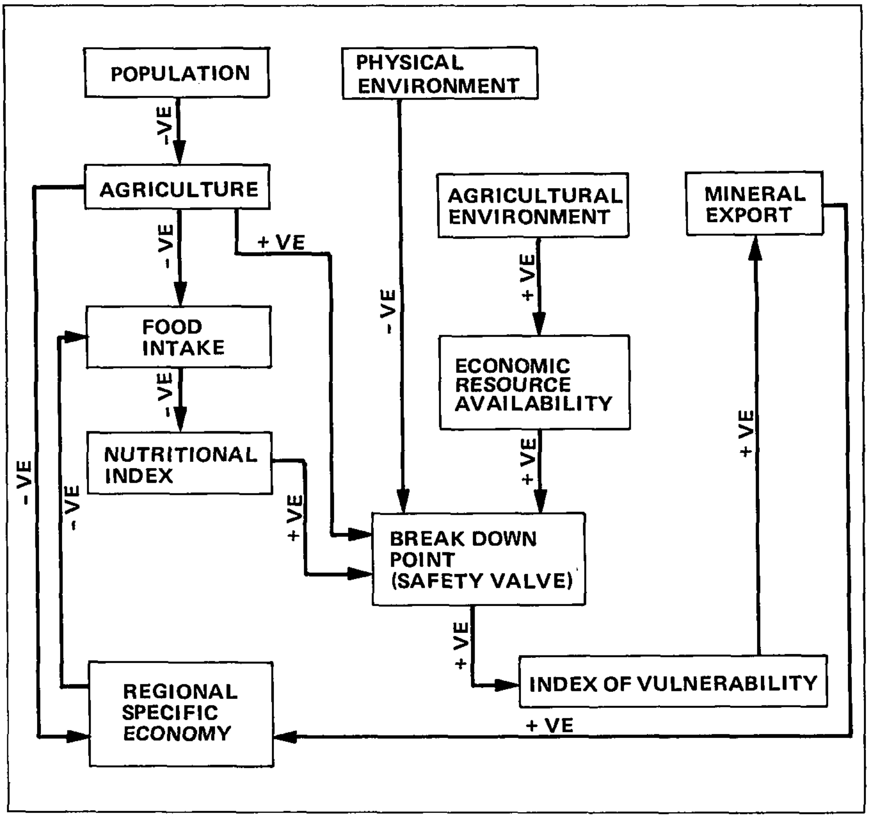

Figure 4. Design for systems approach to food systems and society showing positive and negative feedback loops.

ELEMENTS OF THE SYSTEM

The state of an economy (its ability to sustain its population) is determined by the balance of production and consumption, both in real terms and in terms of exchangeability. In the broadest and most fundamental sense, the components of this system are production and consumption on one side, and food and non-food commodities on the other, thus giving a four-element system.

The primary viability of an economy in human terms is the feeding of its members. Thus a viable society has enough food for its consumption–either by producing or by importing. In order to import, however, there must be something to export, i.e., some non-food commodity. As long as the basic food intake has priority, the community may have to starve itself of some non-food necessities by lowering their consumption through an act of political will. In a healthy economy, net deficits and surpluses will balance out. Other situations may occur, including those in which surplus food is exported to import consumables.

The determinant factors therefore are:

- the balance between food production and consumption,
- the balance between *non-food production and consumption*, and
- the balance between these two.

Different combinations of these define different real situations. These may be categorized as:

Equilibrium states–	$F_c = F_p$, $NF_c = NF_p$	(1)
	$F-$, $NF+$, $F- = NF+$	(2)
	$F+$, $NF-$, $F+ = NF-$	(3)
Surplus states–	$F_b > 0$, $NF_b > 0$	(4)
F_b = Food balance $= F_c - F_p$	$F_b \leqslant 0$, $NF_b \geqslant 0$, $/NF_b/ > /F_b/$	(5)
$NF_b = NF_c - NF_p$	$F_b \geqslant 0$, $NF_b \leqslant 0$, $/NF_b/ < /F_b/$	(6)
Deficit states–	$Fb < 0$, $NF_b < 0$	(7)
	$F_b \leqslant 0$, $NF_b \geqslant 0$, $/NF_b/ < /F_b/$	(8)
	$F_b \geqslant 0$, $NF_b \leqslant 0$, $/NF_b/ < /F_b/$	(9)

Discussion of States

Equilibrium states–

1. A completely internally self-sufficient community; inherently unstable (but dynamic) because of the tendency of lower priority needs to rise so that equilibrium can only be sustained at the cost of deprivation in

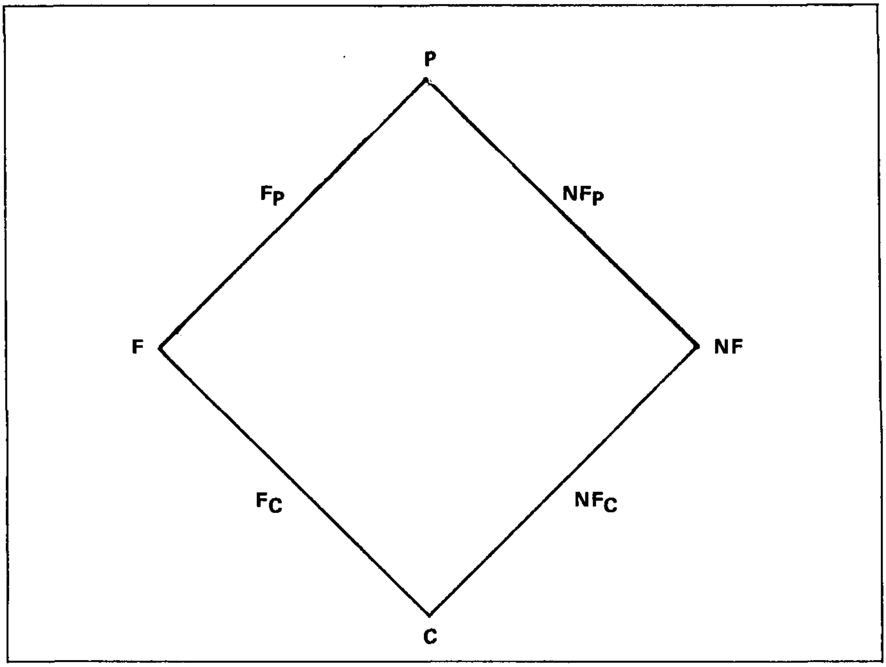

Figure 5. Representation of a graphical method to diagnose the state of any economy with food/non-food production and consumption as major activity components.

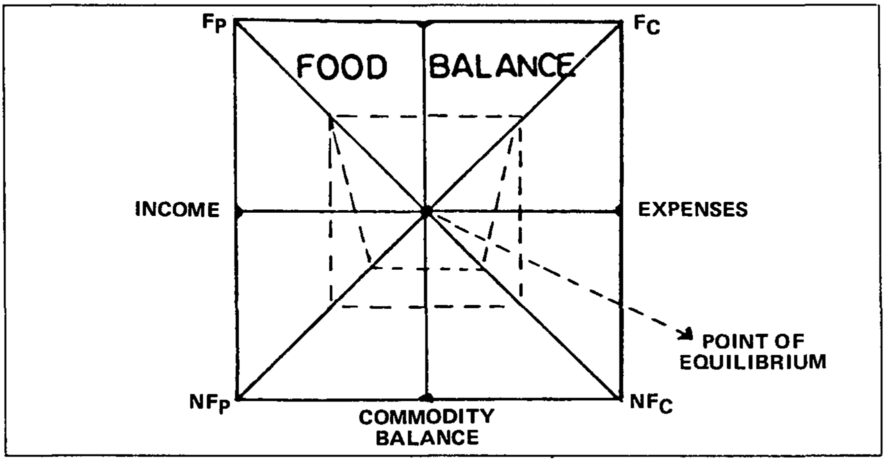

Figure 6. Visualization of the systems structure where the probable path of the movement of disequilibrium to equilibrium can be traced.

non-food consumables (perhaps such deprivation originally secured equilibrium!).

2. A common state (for example the U.S.S.R.) again, the positive NF balance may arise out of a willfully depressed consumption; therefore unstable, but with inbuilt motivation for development.
3. Characteristics similar to 2. (example Austrailia and New Zealand) growing mineral exports are the immediate reaction to the negative NF balance, followed by industrialization.

Surplus states–4., 5., and 6. all transient, since these states provide impetus to increased consumption, and thus move towards equilibrium states.

Deficit states–7. can be remedied only by drastic action; usual positive reactions are intensified efforts in food production and an export of manpower.

8. A widespread phenomenon, perhaps characteristic of the Third World. The trade-off between export of raw materials to support food imports and the need for conservation restrains increased exports. Exports of raw materials are regulated by the importing countries, and a dependency due to the adverse balance perpetuated. Three kinds of responses exist 1) cartelization to extract maximum value of exports, leading to an unsupported high standard of living, (OPEC) b) acceptance of an economy trapped in poverty, and c) a comprehensive attack towards increased food production, industrialization and a consequent influence on export prices (moving away from this state).
9. Another loser economy, since food importers may not be able to export non-food consumables, and repeated exchanges lead to control by broker.

Diagnosis–In order to diagnose the state of any economy, its specific deviations from the equilibrium and the basis for corrective action, a graphical method has been attempted (Figure 5).

The apices of the square represent the production/consumption and food/non-food axes of the matrix, and the sides represent the elements. Since the operative balance is between P and C, the measurements are scaled from these vertices, and each parameter is denoted by a point on the appropriate line. The quantitative scales are separately equal on the food and non-food sides. The food scales are in absolute quantities. The non-food scales are in terms of economic price–i.e., value input/outflow from the system. A locus of equilibria separating the different fields representing the states described can be drawn. By plotting the actual values for any system, its condition can also be specifically diagnosed.

Apart from diagnosing the field, i.e., state, the diagram permits identification of the exact extent and direction of disequilibrium. Done sequentially over a period of time, it also shows the trend of variation.

Combined study leads to prognosis, since the shortest route to the equilibrium can be determined; together with trend, alternate routes can be mapped, representing alternate strategies for intervention. The shortest route need not be the least expensive or the fastest. Intervention requires effectiveness in cost and time, and the method of alternate mapping as adopted approaches an optimal solution.

Intervention requires effectiveness in cost and time. Figure 5 is theoretically devised to determine the specific point, direction and length of corrective intervention. Figure 6, derived from Figure 5, is shown to project the system that is visualized, where the probable path of movement of disequilibrium can be traced. On the other hand, a tendency to migrate outside the shown trapezohedron would indicate vulnerability to oscillation disequilibrium.

EVOLUTION AND HEURISTIC MODELLING

The three primary activity nodes of the total food environment of any region constitute *geosystem, ecosystem* and *socioeconomic system* occupying the apices of a triangle (Figure 7). Geosystem, the source, by interaction within itself, improves to ecosystem; agriculture is derived from an interaction of ecosystem and socioeconomic system; and industry occupies a position on the

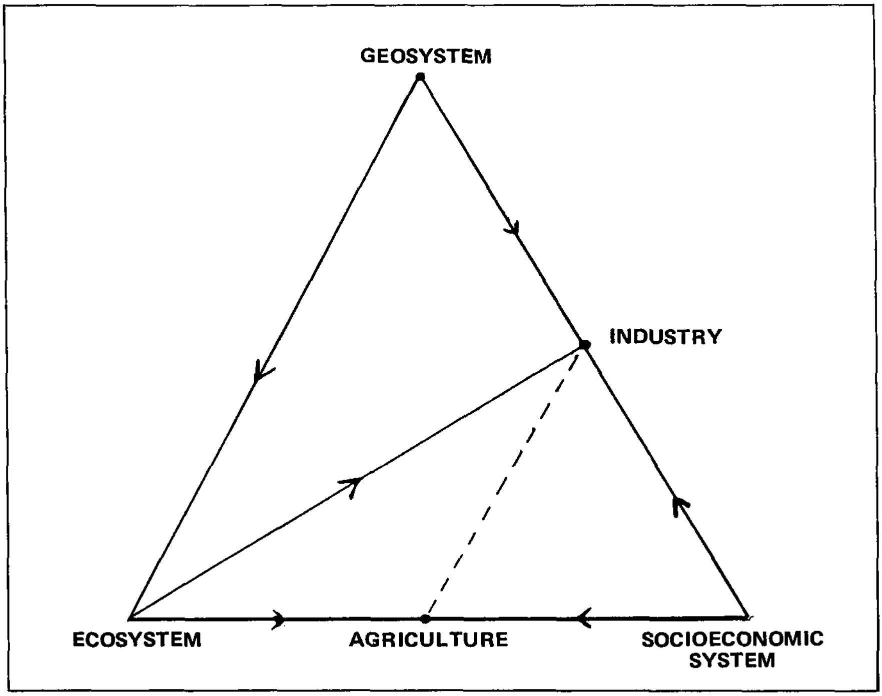

Figure 7. Ternary phase diagram of the food systems and society.

equilibrium line connecting socioeconomic system and geosystem nodes where ecosystem intervenes.

It is postulated that if equilibrium exists between these activity nodes in an environment the population would not be vulnerable to famine. Any other condition outside this equilibrium zone would cause famine. However, the income of the population concerned involved in production/consumption of food and non-food in an environment has to be taken into account in any model describing famine. The interrelationship is diagrammatically shown in Figure 8 and the relevance of income for famine state is shown in Figures 9 a and b.

The three components–*income, production* and *consumption* have been combined together in theoretically varying random proportions in Figure 10 to find out the heuristic equilibrium field of equal export and import (both for food and non-food) i.e., $F_{export} = NF_{import}$ and $F_{import} = NF_{export}$ which should define fields of net surplus/deficit on either side. This balance of trade will be able to sustain an equilibrium between production/consumption and income (we may take value added in non-food production in each district as local income) involving food and non-food sectors. It would consequently be able to resist

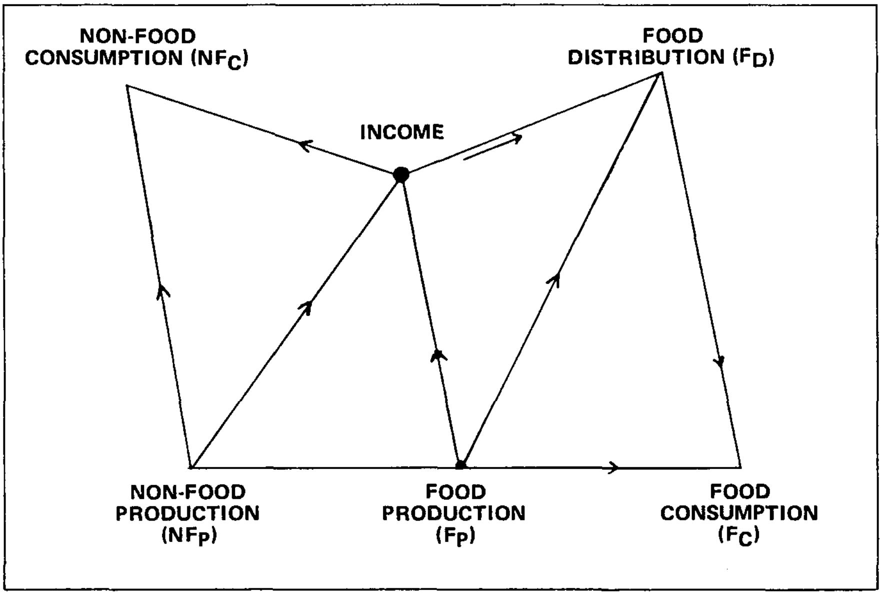

Figure 8. Diagrammatic representation of food-income interrelationship in any natural environment.

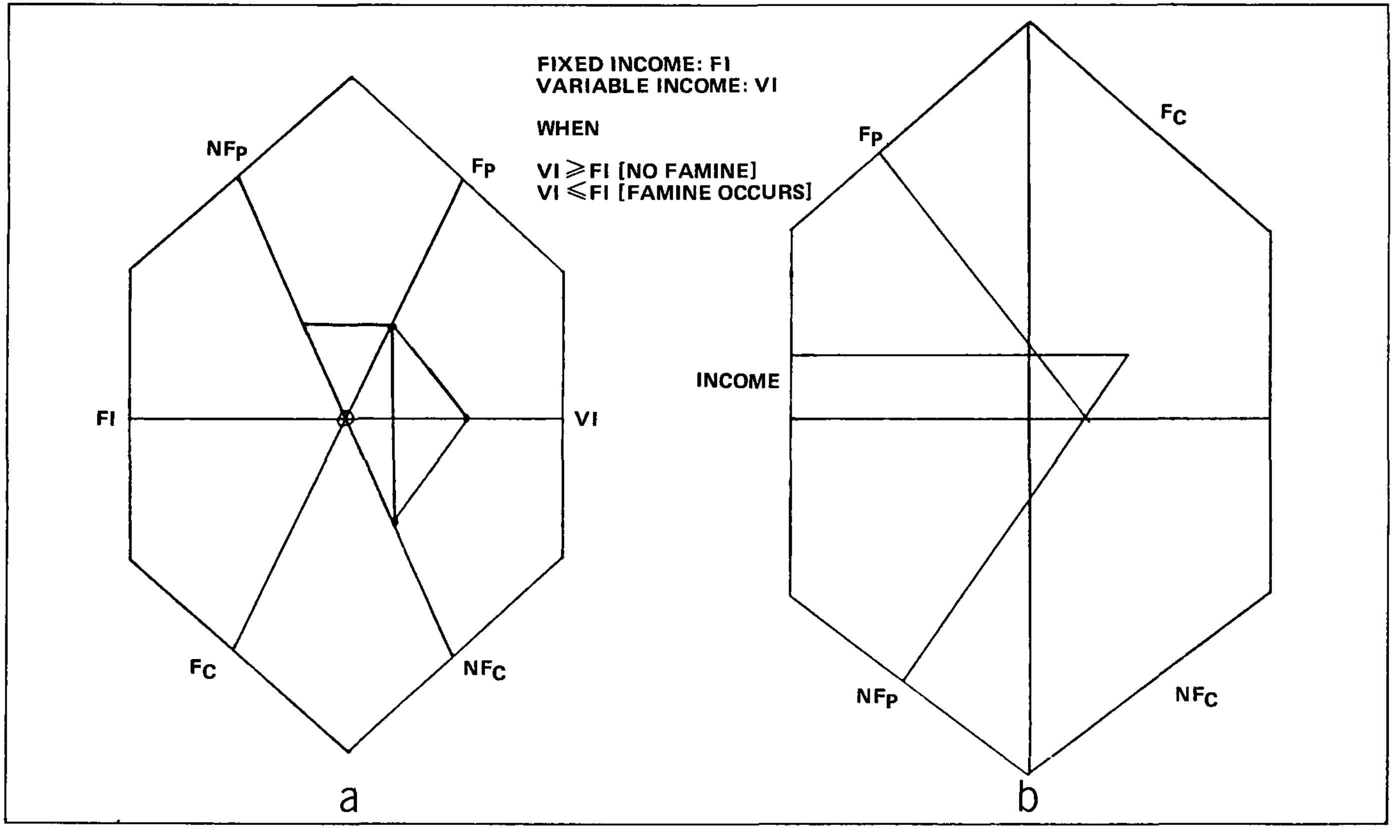

Figure 9. Theoretical representations of income–food/non-food relationships in famine and non-famine states.

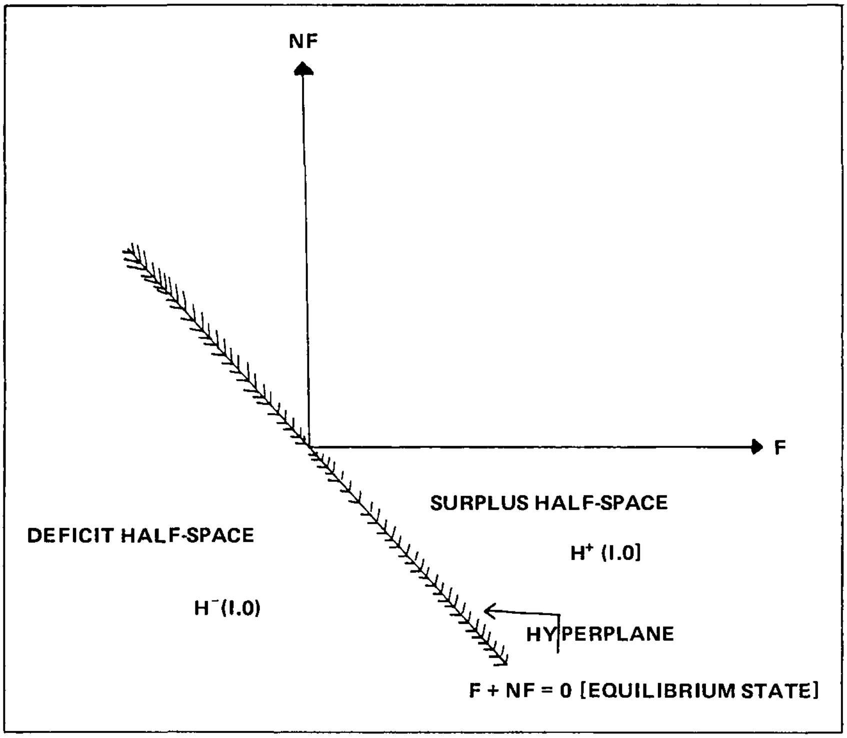

Figure 10. Space definitions of equilibrium, deficit, and surplus states in the food systems and society model.

famine in a congruent physical environment. This condition is particularly applicable to India where the agricultural economy is in a 'trapped' state.

The various combination of F_p, NF_p, F_c, and NF_c (p = production, F_p = food production, NF_p = non-food production, c = consumption, F_c = food consumption, NF_c = non-food consumption) were computerized to define the equal export/import field and the other fields identified are: (Figure 11)

	Food Balance	*Commodity Balance*
(a)	–	–
(b)	0	0
(c)	0	+
(d)	+	0
(e)	+	+
(f)	–	0
(g)	–	+
(h)	0	–
(i)	+	–

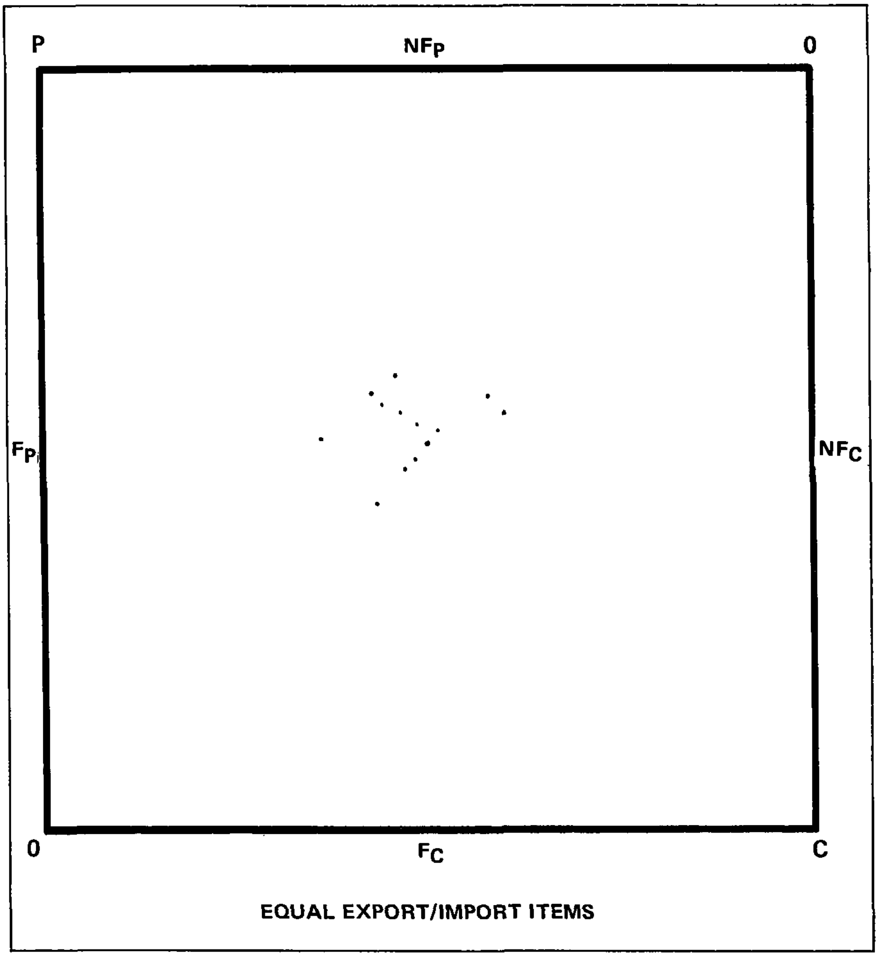

Figure 11. Computerized representation of the theoretically defined equal export/import field involving food production, non-food production, food consumption and non-food consumption of a natural environment with special reference to developing economies.

The locus of equilibrium as evident from the present computerized model seems to be represented by a curve, and the intervention required to bring the non-equilibrium fields to this equilibrium should be measured out in terms of F and NF. This can define the minimum, and thus optimum, intervention in terms of modification of production and economic steps to avoid famine, and also indicate the direction of such critical intervention.

Again, we know that $F_c, F_p, NF_c, NF_p \geqslant 0$.

Let

$$F = F_p - F_c = \text{surplus of production over consumption for food items}$$

and

$$NF = NF_p - NF_c = \text{surplus of production over consumption for non-food items}$$

then the *equilibrium states* can be defined as:

(a) $F + NF = 0$ where F and NF are unrestricted in sign.

The *surplus states* can be defined as:

(b) $F + NF > 0$ where F and NF are unrestricted in sign and deficit states can be enumerated as:

(c) $F + NF < 0$ where F and NF are unrestricted in sign.

(a) $F_p - F_c + NF_p - NF_c = 0$ (*Equilibrium* State)
$F_p, F_c, NF_p, NF_c \geqslant 0$

(b) $F_p - F_c + NF_p - NF_c > 0$ (*Surplus* State)
$F_p, F_c, NF_p, NF_c \geqslant 0$

(c) $F_p - F_c + NF_p - NF_c < 0$ (*Deficit* State)
$F_p, F_c, NF_p, NF_c \geqslant 0$

The formulation thus reduces the fields described early into three well defined geometric spaces.

In Euclidean space E_2 we have the vectors

$$\underset{\sim}{U} = (F, NF)$$

The Equilibrium states (Figure 10) $F. + NF = 0$, can be represented as $(1,1)\binom{F}{NF} = 0$ or $\underset{\sim}{I}.\underset{\sim}{U}' = 0$ where $I = (1,1)$ and $\underset{\sim}{U}' = \binom{F}{NF}$. This represents a hyperplane in E_2, synoptically written as:

$$H(\underset{\sim}{I}, 0)$$

This hyperplane $H(\underset{\sim}{I}, 0)$ divides E_2 into two half spaces which may be denoted by:

$$H^+(\underset{\sim}{I}, 0) = (\underset{\sim}{U} \mid I.U' > 0, U \geqslant \underset{\sim}{0}) \qquad \text{[Surplus Space]}$$

$$H^-(\underset{\sim}{I}, 0) = (\underset{\sim}{U} \mid I.\underset{\sim}{U}' < 0, U \geqslant \underset{\sim}{0}) \qquad \text{[Deficit Space]}$$

If we assume variables as F_p, F_c, NF_p, NF_c then the space under consideration will be constrained on the positive quadrants only as:

$$\begin{pmatrix} F_p \\ F_c \\ NF_p \\ NF_c \end{pmatrix} \geqslant \underset{\sim}{0}$$

The magnitude of surplus/deficit of any point may, however, be measured by the perpendicular distance upon the hyperplane from the point and this projection would be considered to be positive when the point lies on $H^+(I,0)$ half space and negative where the point lies on $H^-(I,0)$ half space.

For example, where the hyperplane is represented by the equation

$$F + NF = 0$$

then for any point (F_0, NF_0), the magnitude of surplus/deficit is given by

$$\frac{F_0 + NF_0}{\sqrt{2}}$$

and thus the intervention required, if any, is identified.

ACKNOWLEDGMENT

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It is expected that the present investigation will stimulate further work in this field, and the model refined with the input of field data.

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