Defining Developmental Problems for System Dynamics Modeling: An Experiential Learning Approach[1]

Khalid Saeed
Social Science and Policy Studies Department
Worcester Polytechnic Institute
Worcester, MA 01609, USA
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Abstract

Developmental problems are often perceived as existing conditions, which must be alleviated. This often removes a policy from the factors that created the problem in the first instance. This paper suggests that a developmental problem must be defined as an internal behavioral tendency found in a system, so its causes can be determined before a corrective policy is initiated. Such a problem description is called a reference mode in system dynamics modeling; it identifies the boundary of a model that could be built and experimented with to identify appropriate policy actions. The characteristics of a reference mode and how it might differ from a historical record are stated. An experiential learning model reported earlier by the author elsewhere is applied to delineate the four learning cycles entailed in constructing a reference mode. This model is then applied to constructing a reference mode addressing the food security problem in Asia using time series date from fourteen selected countries. Food security problem defined in this way would lead to policies that are different from those emphasizing increases in food production.

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[1] This paper emerged out of my efforts to teach system dynamics at WPI. I appreciate the encouragement of my colleagues and students, whose penetrating questions led to the growth of the problem definition process from one learning cycle to two, then to three and finally to four. I particularly appreciate the feedback from my colleague Isa Bar-On who reminded me that I was being lazy in my initial efforts in not bringing to fore all steps in the process.

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Introduction

Developmental problems are often perceived as pre-existing conditions, which must be alleviated. For example, food shortage, poverty, unequal income distribution, high illiteracy rate, low infrastructure inventory and corruption are often defined as developmental problems. In all such cases, the starting point for a policy search is the acceptance of a snapshot of the existing conditions. A developmental policy is then constructed as a well-intended measure that should improve existing conditions. Experience shows that policies implemented with such a perspective not only perform variedly, they also create unexpected results. This happens since the causes leading to the given conditions are often not understood. The well-intentioned policies only create ad hoc changes, which are often overcome by the system's reactions.

Development policy must adopt a problem solving approach in a mathematical sense if it is to achieve reliable performance. In this approach, a problem must be defined as an internal behavioral tendency found in a system and not as a snap shot of existing conditions. It may represent a set of patterns, a series of trends or a set of existing conditions that appear resilient to policy intervention. In other words, an end condition by itself must not be seen as a problem definition. The complex pattern of change implicit in the time paths preceding this end condition would, on the other hand, represent a problem. The solution to a recognized problem should be a solution in a mathematical sense, which is analogous to creating an understanding of the underlying causes of a delineated pattern. A development policy should then be perceived as a change in the decision rules that would change a problematic pattern to an acceptable one. Such a problem solving approach can be implemented with advantage using system dynamics modeling process that entails building and experimenting with computer models of problems, provided of course a succinct problem definition has first been created.

I'll discuss in this paper the process of defining a developmental problem for subsequent modeling and analysis, which I view to be an experiential learning process involving sixteen steps constituting four learning cycles. Called a reference mode in system dynamics, such a problem definition is based on historical information and is often described in a graphical form. I'll also illustrate the process of constructing a reference mode with an example addressing the food security problem in Asia. The reference mode constructed in this paper as an illustration has been used in Saeed (1992a) for building a system dynamics model to understand the food security problem in Asia.

Does historical behavior represent a reference mode?

Having said that a snapshot of given conditions does not represent a developmental problem, I would like to add that historical behavior by itself is also not an adequate description of a reference mode, although it is a shade better than a snapshot. A reference mode is a fabric of trends representing a complex pattern rather than a collection of historical time series. It may contain variables actually existing in historical data as well as those summarizing qualitative information from a related body of knowledge, or those concerning policy options to be explored. Historical data is only a starting point for constructing a reference mode, which is an abstract concept that must be developed very carefully from the historical data and the inferred future patterns it points toward.

At the outset, while both historical behavior and a reference mode can be expressed in either quantitative or descriptive terms, a reference mode is essentially a qualitative and intuitive concept since it represents a pattern rather than a precise description of a series of events. A reference mode also subsumes past history, extended experience and a future inferred from projecting the inter-related past trends. It can be seen with the mind's eye as an integrated fabric, although it can be represented on paper only as isolated tendencies. A reference mode will also not contain random noise normally found in historical trends, as this noise lies outside of the deterministic process underlying our understanding of the system behavior. Finally, a reference mode is an integrated fabric that can only be visualized in the abstract, although it can only be represented in a graphical form on a two-dimensional block. Fortunately, we have an immense experience of visualizing such a fabric due to the constant demand made on our perceptions to convert limited perceptual images of reality into more comprehensive mental images. For example, a two-dimensional vision frame that our eyes construct can be perceived as a three-dimensional mental image by our mind [Abbot 1987].

An experiential learning framework for constructing a reference mode

I have pointed out in Saeed (1998), that system dynamics modeling process is best implemented using an experiential learning framework originally proposed by Kolb (1984). Kolb's model of experiential learning, originally proposed in an organizational learning context, draws on the faculties of observation, concrete thinking, experimentation and reflection [Kolb 1984, Hunsacker and Alessandra 1980, Kolb, et. al. 1979, Kolb 1974, 1998]. It requires that an abstract concept be developed through a learning approach calling upon all four faculties as illustrated in Figure 1.

Kolb's learning cycle is driven by four basic faculties: watching, thinking, doing and feeling. For the learning process to be effective, watching must result in careful observation of facts, leading to discerning organized patterns. These patterns then must drive thinking, which should create a concrete experience of reality. The implications of the concrete experience must be tested through experimentation conducted mentally or with physical and mathematical apparatuses. Finally, this experimentation must be translated into abstract concepts and generalizations through a cognitive process driven at the outset by feeling, which would, in turn, create further organization for careful observation thus invoking another learning cycle.

The learning faculties, according to Kolb's model, reside in two basic human functions, physical and cognitive - each integrated along two primary dimensions, which are also illustrated in Figure 1. The first dimension, concerning the physical functions is passive – active. The second, concerning the cognitive functions is concrete – abstract. Thus, the faculty of watching is a passive physical function, thinking a concrete cognitive function, doing an active physical function and feeling an abstract cognitive function. Since the mental construction of reality and its interpretation must filter unwanted information, each faculty must be guided by certain organizing principles to affect learning. Additionally, the learner is required to shift constantly between dissimilar abilities to create opportunities for refuting the anomalies, which would appear among the constructs of each ability.

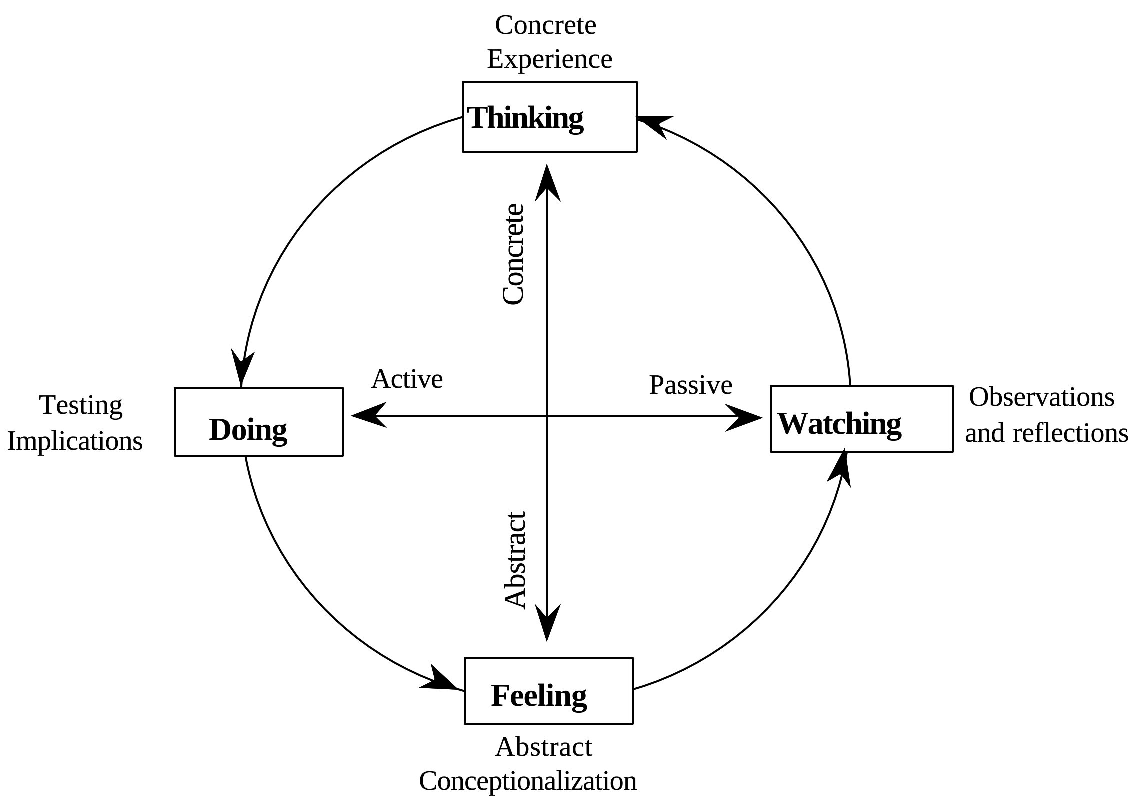


Figure 1 **Kolb's model of experiential learning**

The development of a reference mode requires integration of four abstract concepts, 1) delineation of a system boundary, 2) recognition of a fabric of historical patterns within the defined system boundary and 3) recognition of past trends for policy related variables missing in historical data, and 4) projecting past trends into future to create a fabric of inter-related patterns that constitutes a reference mode. It is accomplished through implementation of an undocumented process an experienced modeler follows to construct a reference mode. This process entails sixteen steps built around four learning cycles as shown in Figure 2. They are described below:

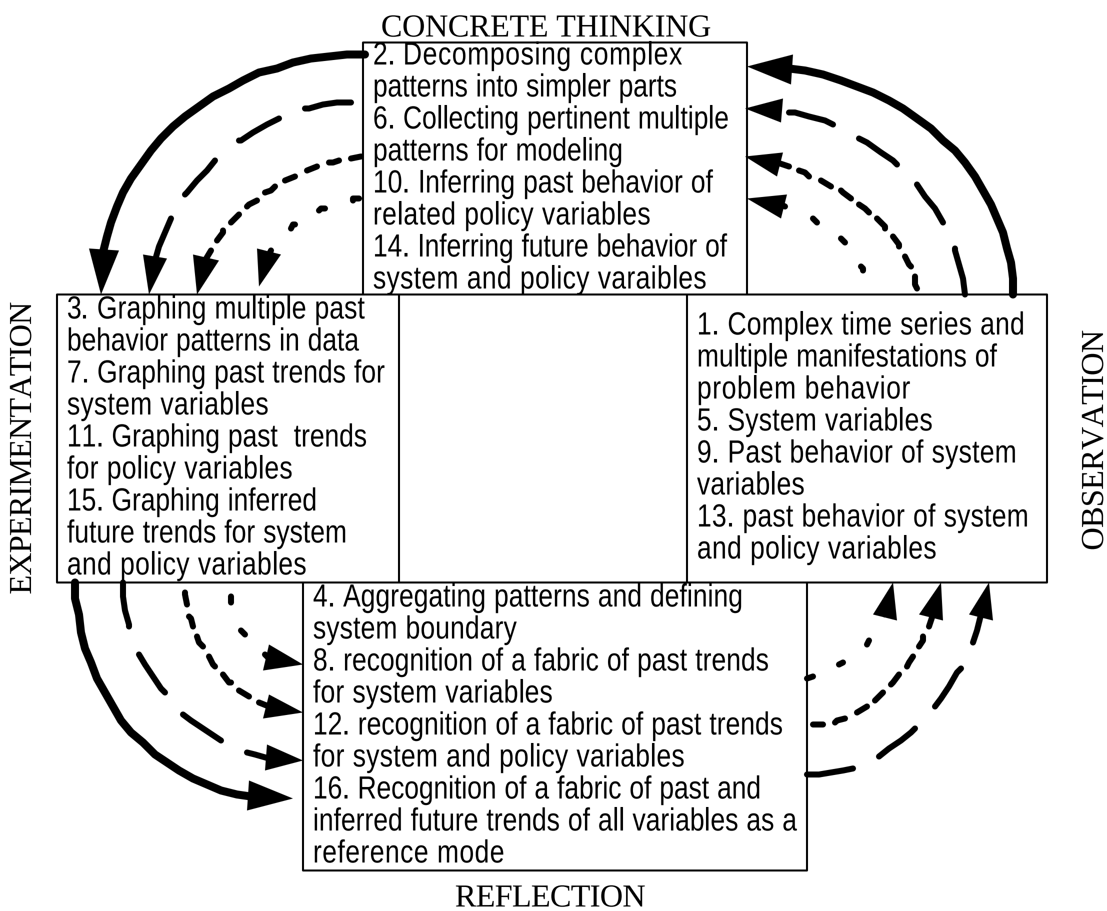


Figure 2 Sixteen steps involved in the construction of reference mode

a) First learning Cycle: Delineation of a system boundary

One must begin by 1) carefully examining historical information both quantitative and qualitative residing in the complex time series and event descriptions as well as in the multiple manifestations of the problem behavior in different periods and in different places. 2) This is followed by decomposition of observed complex patterns into simpler parts. 3) Next, a round of experimental graphing creates simple multiple patterns representing slices of the complex behavior one has set out to model. 4) A careful examination of the decomposed graphs helps delineate the system boundary in terms of the variables that must be considered to describe the discerned patterns. These variables may or may not be the same as in the historical data. Some of the variables in the data can be aggregated while others substituted with more abstract concepts, depending on the problem focus, and the time horizon of interest. The time horizon of reference mode depends on the purpose of the model, but it would invariably be longer than the historical information it is based on, as it would include also information about the inferred future.

b) Second learning cycle: Recognition of a fabric of past trends within the defined system boundary

The second learning cycle begins with 1) a careful examination of the variables discerned within the system boundary. 2) The multiple patterns related to these variables are then collected into groups representing multiple modes of behavior separated by time and geography. 3) A second round of graphing past trends addresses system variables and their multiple modes as differentiated from the first round that concerned historical data. 4) Finally, the drawn trends are recognized as a multi-dimensional fabric representing past problem history.

c) Third learning cycle: Constructing a system of past trends for policy variables missing from historical data

While a model that replicates past history can be constructed without building an adequate policy space in it, such a model is often not useful in terms of exploring an operational means for system improvement. Experimentation with such a model would often lead to normative statements about what should be done, not what can be done, to improve system behavior. To create an adequate policy space in the model, structure representing policy decisions must be included although information about the behavior of policy-related variables may not exist in the historical data. For example, if potential policies concern resource management, policy space representing choice of resources and technology should be included. If they concern delivery of certain services, the role of institutions delivering those services and how such institutions are to be supported should be included. If taxation and expenditure instruments are possible policy instruments, the mechanisms of their determination and impact should be included.

Construction of past patterns of behavior for the policy variable would often require going through an additional learning cycle that begins with 1) a careful examination of the past behavior of the delineated system variables, followed by 2) inferring behavior of related policy variables for which one might often have to delve into the empirical or the theoretical premises of policy. Next, 3) an attempt is made to graph the past patterns of behavior for the policy variables which when 4) combined with the already drawn past trends for the system variables create an integrated fabric of past trends.

d) Fourth learning cycle: projecting past trends into future to create a reference mode

The third cycle begins by 1) carefully examining the past behavior of system variables paying special attention to their phase relationships and relative positions. 2) Next, these trends are intelligently projected into the future keeping in view the progression of the whole fabric instead of concentrating on one trend at a time. This process might often bring to fore any turning points in system behavior that would appear if current policies continue to be practiced. 3) A third round of experimental graphing extrapolated trends creates essential components of a reference mode; and 4) the graphed trends representing past behavior of the system variables, policy variables and their inferred future viewed as a fabric finally define the reference mode representing a succinct description of developmental problem.

A reference mode so constructed can be readily related to the information in the micro-structure domain for formulating a dynamic hypothesis and eventually building a model. A dynamic hypothesis constructed from such a reference mode would often fall into an archetypal category since the decomposition process creates organized generic patterns discerned from situational unique patterns. A model constructed to represent this reference mode would address multiple manifestations of a problem and would incorporate in it the policy space for transforming one pattern to another, which is an important goal of system dynamics modeling. The following section illustrates above process using real data.

An illustration of the problem definition process: Agricultural land use and food security in the Asia and the Pacific Region - A tragedy of the commons in the making?

Some time ago, I prepared a background paper for the United Nations Economic and Social Commission for Asia and Pacific (UN-ESCAP) on environmental trends and their future projection in the Asia and Pacific Region [Saeed 1994]. Since projections were required for an extended period of time and could not possibly be based on a simple trend extrapolation, I adopted the process of constructing a reference mode to create intelligent projections. Also, since the region in question consisted of many countries, we were definitely dealing with multiple manifestation of the problem. I'll illustrate here how the historical data was used to determine the food production pattern in the region covering past as well as inferred future behavior following the four learning cycles described in the last section.

The first was to organize the available numerical data so it could give information about the whole region. A complementary effort was also launched to review the related qualitative information to identify pertinent policy-related variables. Some 300 time-series, covering past three decades and representing fourteen selected countries representing the Asia and Pacific region, were constructed from published UN sources to serve as a data-base for the analysis. There were many missing cells in the data. Also, there were differences in units and definitions of data categories and national policies across countries. Last but not least, there were great differences across countries in terms of size and the volume of activity represented in the data, hence any aggregation could lead to domination of aggregate data by one or more larger countries.

The selected countries were divided into three categories based on per capita income each expected to characterize a different manifestation of the problem pattern. Australia, Japan, Korea and Singapore were placed in category (A), representing relatively high levels of income. Malaysia, Thailand, Philippines, and Indonesia were placed in category (B), representing middle levels of income. China, India, Nepal, Pakistan, Sri Lanka, and Vietnam were placed in category (C), representing relatively low levels of income. This classification was incidentally consistent with the one proposed by the Asian Development Bank [Okita 1989]. It also covered the variety of the countries in the Asia and Pacific region well, in terms of geographic location, form of government and economic conditions.

Although, above data format was partly necessitated by the quality of the data available, it greatly facilitated making general inferences concerning the whole of the Asia and the Pacific region. The individual differences between the data elements, in this case the country-specific time series allowed the data to be viewed as a sample representing the region it was drawn from. The countries in the various categories of the sample were not viewed as special cases, but as multiple manifestations of the behavior of the agricultural system of the region. A reference mode was constructed from above data following the process outlined in the last section. The specific steps taken are described below:

a) Determining system boundary

The historical data was divided into two broad categories respectively representing: i) the growth of consumption base; and ii) the condition of renewable agricultural resources. Time series plots for the various categories of countries were prepared for population, GDP and GDP per capita to examine growth in the consumption base. The use of agricultural resources was examined through Per Capita Food Production Index, Fertilizer and Pesticide Application, Cultivable Land, and Area under Forests.

Following observations were made regarding each category covering steps 1 and 2 in first learning cycle of Figure 2:

i) Growth of the Consumption Base

Figures 2: a, b and c show population and GDP growth in the three categories of countries selected for the analysis. Considerable population growth is shown over the three decades covered by the data in all categories, although growth is much higher in the low-income countries. GDP growth is the highest in the middle-income countries, while growth rates in the high- and low- income countries are comparable. Consequently, as shown in Figures 3: a, b and c, GDP per capita has grown at comparable rates in the high- and medium- income countries due to moderate population growth in the former and high economic growth in the later. However, high population growth rates and moderate economic growth have led to stagnation in GDP per capita in the low-income countries.

According to the projections of UNCHS, shown in Figures 4: a, b and c, tremendous growth has also occurred in urban populations across the board and the high growth rate is expected to continue, although these rates are projected to taper off in the high-income countries. On the other hand, rural populations have shown stagnating or declining trends in the higher income countries and may be expected to decline further in the future. However, due to the overall momentum of population growth, rural population has risen significantly in the medium- and low- income countries, but is expected to taper off and begin to decline over the second decade of the twenty-first century.

As also shown in Figures 4: a, b and c, the total population is expected to continue to rise in all countries well into the twenty-first century, although the rates of projected population growth are negatively correlated with the levels of income. Thus, the lower income countries experience higher and continued rates of total population growth and urbanization [UNHS 1987]. Urbanization also encroaches on prime agricultural land, thus reducing overall land productivity. It also creates concentrated demand on critical natural resources like water, clean air, etc., whose depletion would also lower agricultural productivity. In all cases, there is growth in the consumption base originating from two sources, growth and concentration of population and expansion in economic activity.

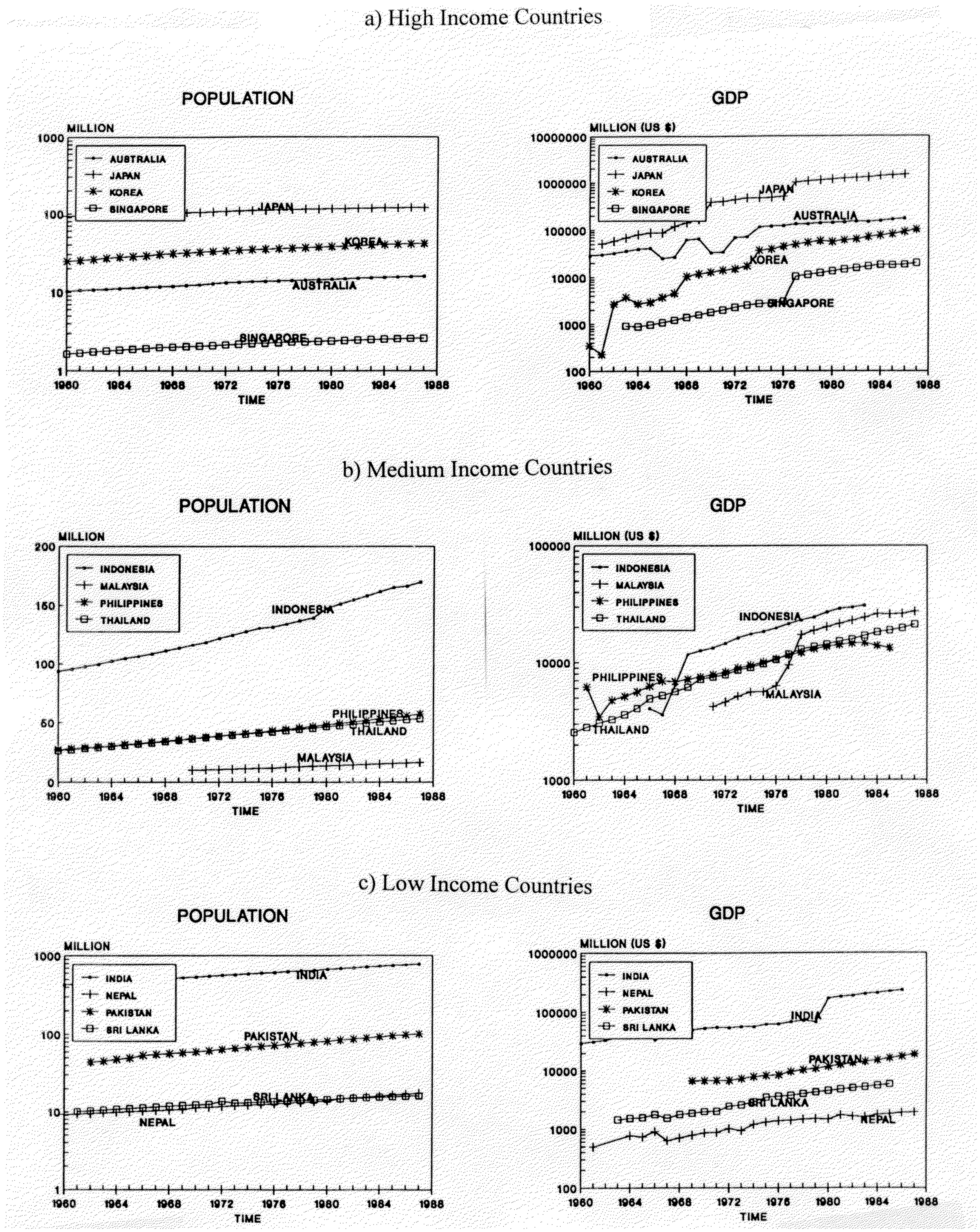


Figure 2 Population and GDP growth

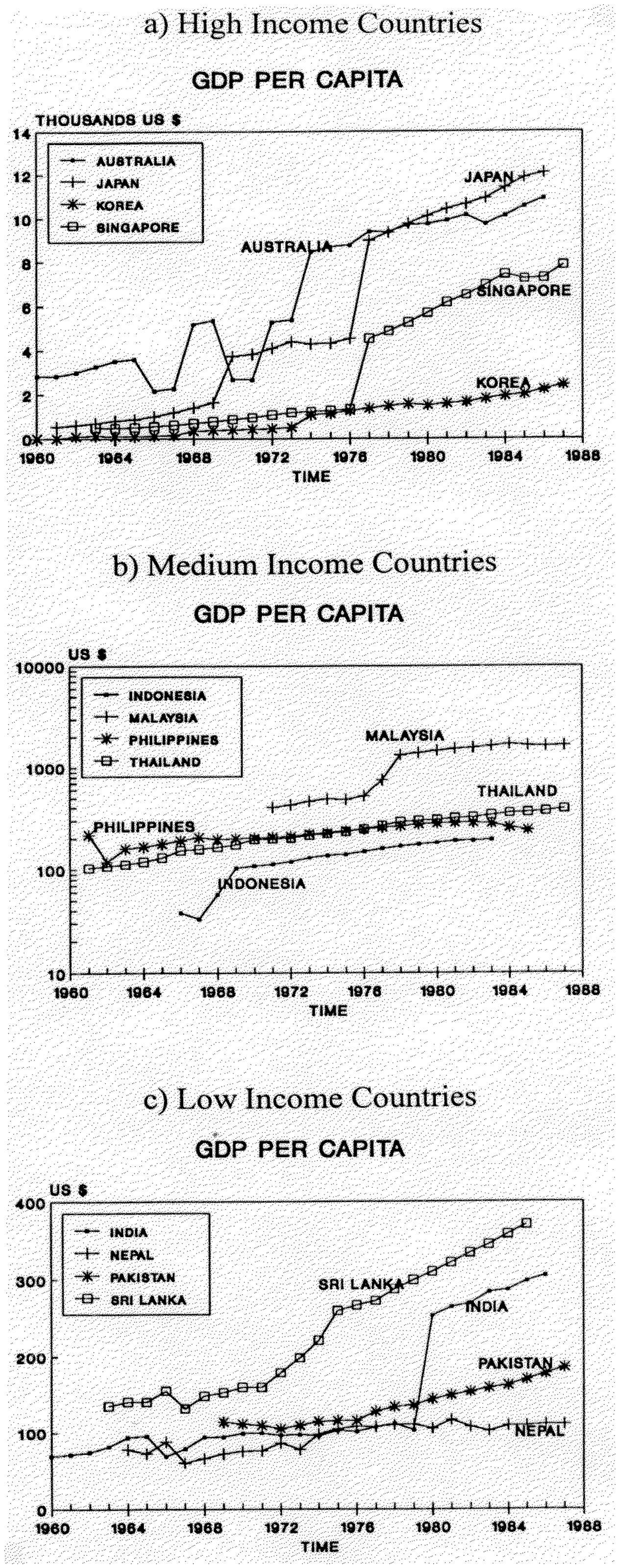


Figure 3 GDP per capita growth

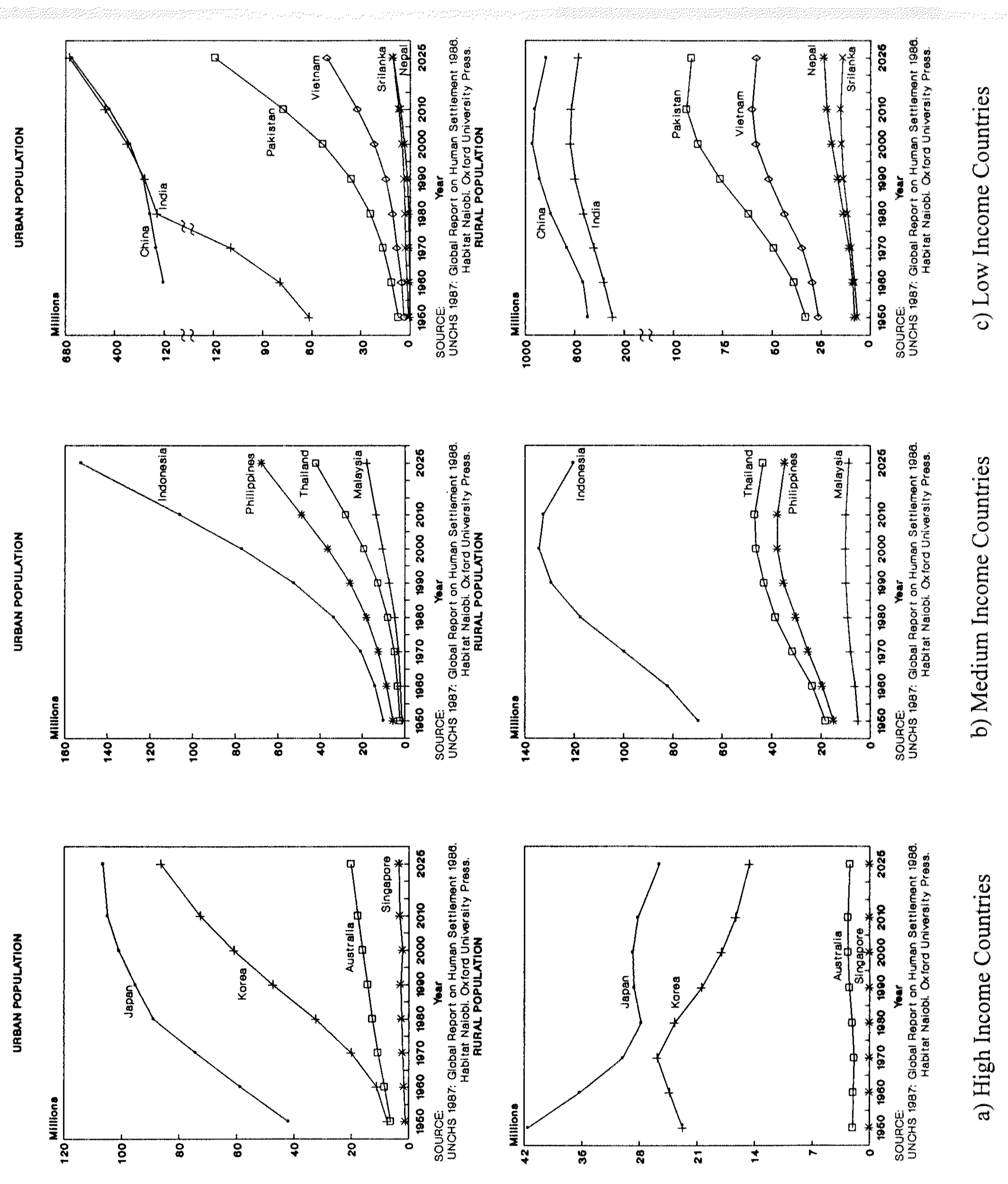


Figure 4 **Projections for urban and rural population**

Figure 5 shows experimental graphs created to represent the various observed patterns observed in the data concerning the growth of the consumption base. Since projections for population are available, these are included. H, M and L represent respectively the high income, the middle income and the low-income countries.

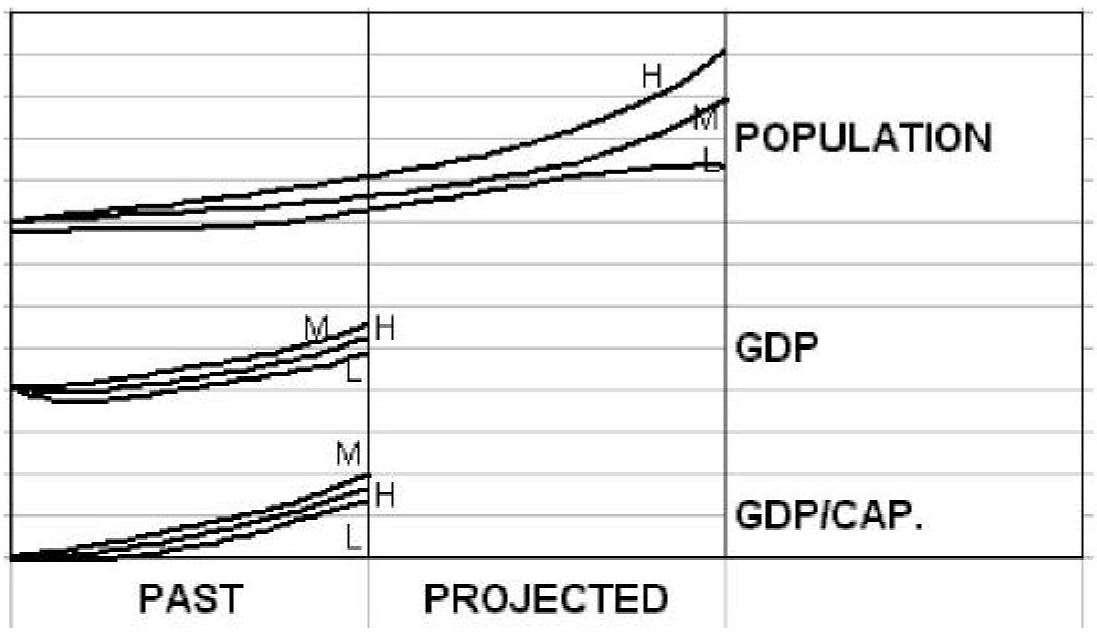


Figure 5 Graphical patterns representing past growth of consumption base

ii) Condition of Renewable Agricultural Resources

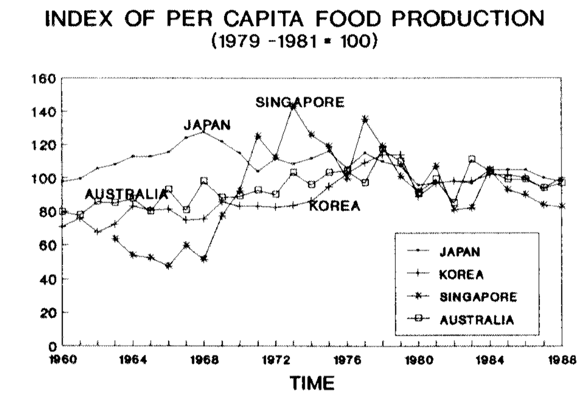
Renewable resources considered include agricultural land and forests, which have traditionally met the food, fuel and timber needs of society. Figures 6: a, b and c show past trends in food production per capita and agricultural land per capita in the countries of the three designated categories of the sample. The food production index is not comparable across selected countries due to differences in the criteria used for calculating the base figures, but represents only an internal measure of the changes in food availability in each country. Some autonomous jumps also appear in the data since it has been constructed from many sources, which although mostly published by the UN, contains some inconsistencies in the definitions used to represent the various categories of data. For the purpose of constructing a reference mode, however, long-term patterns of trends rather than numerical values of the time series are to be compared across the countries of the sample. Hence, the above problems could be tolerated.

It is observed that food production per capita exhibits a rising trend in all cases in spite of considerable population growth, while agricultural land per capita shows a declining trend, except in Australia, where it has been possible to maintain it at a steady level. This indicates that increases in food production have been obtained largely through increasing the intensity of cultivation and application of chemical fertilizers and pesticides. Indeed, as indicated in Figures 7: a, b, and c, fertilizer application has drastically increased in all countries of the sample over the past three decades. The application of pesticides also seems to have increased in the countries where data is available. The pesticides data, however, is inconsistent since in some cases it refers only to DDT while in others it covers all pesticides.

Irrespective of the increases in yield, the absolute quantity of cultivable land has not increased much in most of the countries of the sample, except in Australia, where it has been possible to commission large tracts of unused land. This is shown in Figures 8: a, b, and c. It is observed that, in general, where cultivable land did increase, it was at the cost of the forest area, which is already very small in the countries with a stagnant level of land under agriculture. Some jumps again appear in the plotted data, due to the changes in the definitions of the forest area and agricultural land categories used.

Unfortunately, deforestation not only reduces valuable timber and fuel wood resources, it is also known to cause soil erosion, water loss, flooding or drought, desertification and silting of irrigation reservoirs, depending on the particular function of a forest in the complex organic relationships existing in the ecological system [Bowonder 1986]. In spite of this knowledge, about half of the area under forests in the developing countries was cleared between 1900 and 1965. At current rates of deforestation, the rest is likely to disappear in 50 years [UN-ESCAP 1986].

a) High Income Countries



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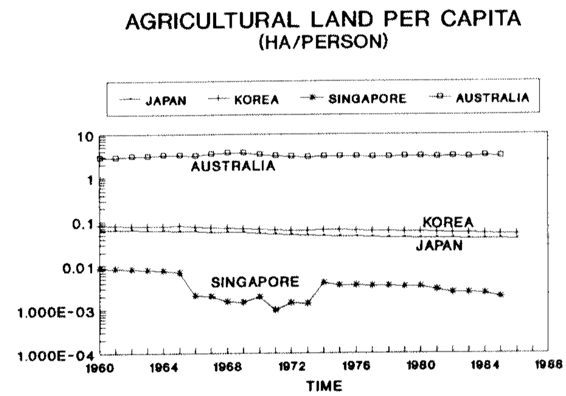

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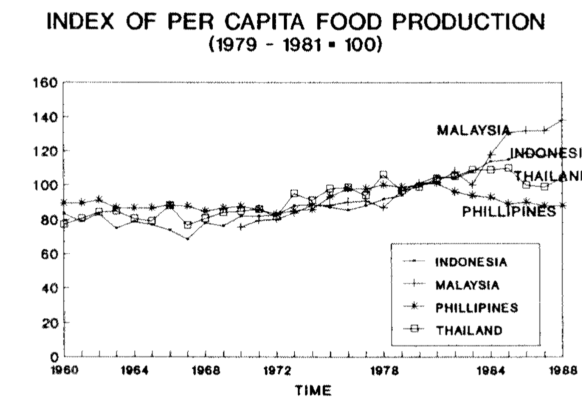
UN 1979: Demographic Yearbook 1978. NY.

b) Medium Income Countries



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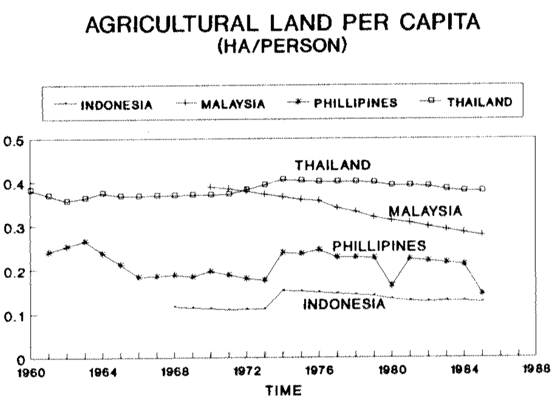

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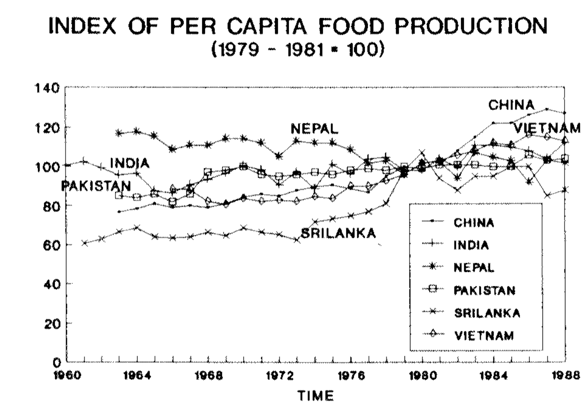
c) Low Income Countries



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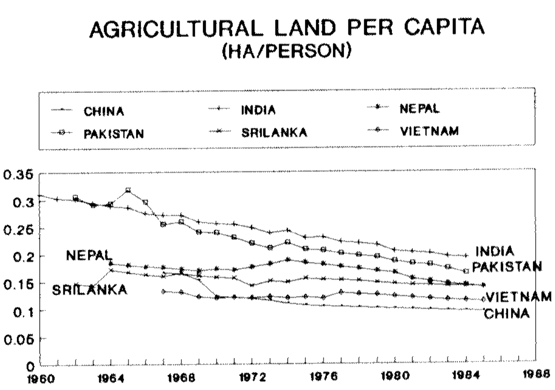

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Figure 6 Food Production per capita and agricultural land per capita

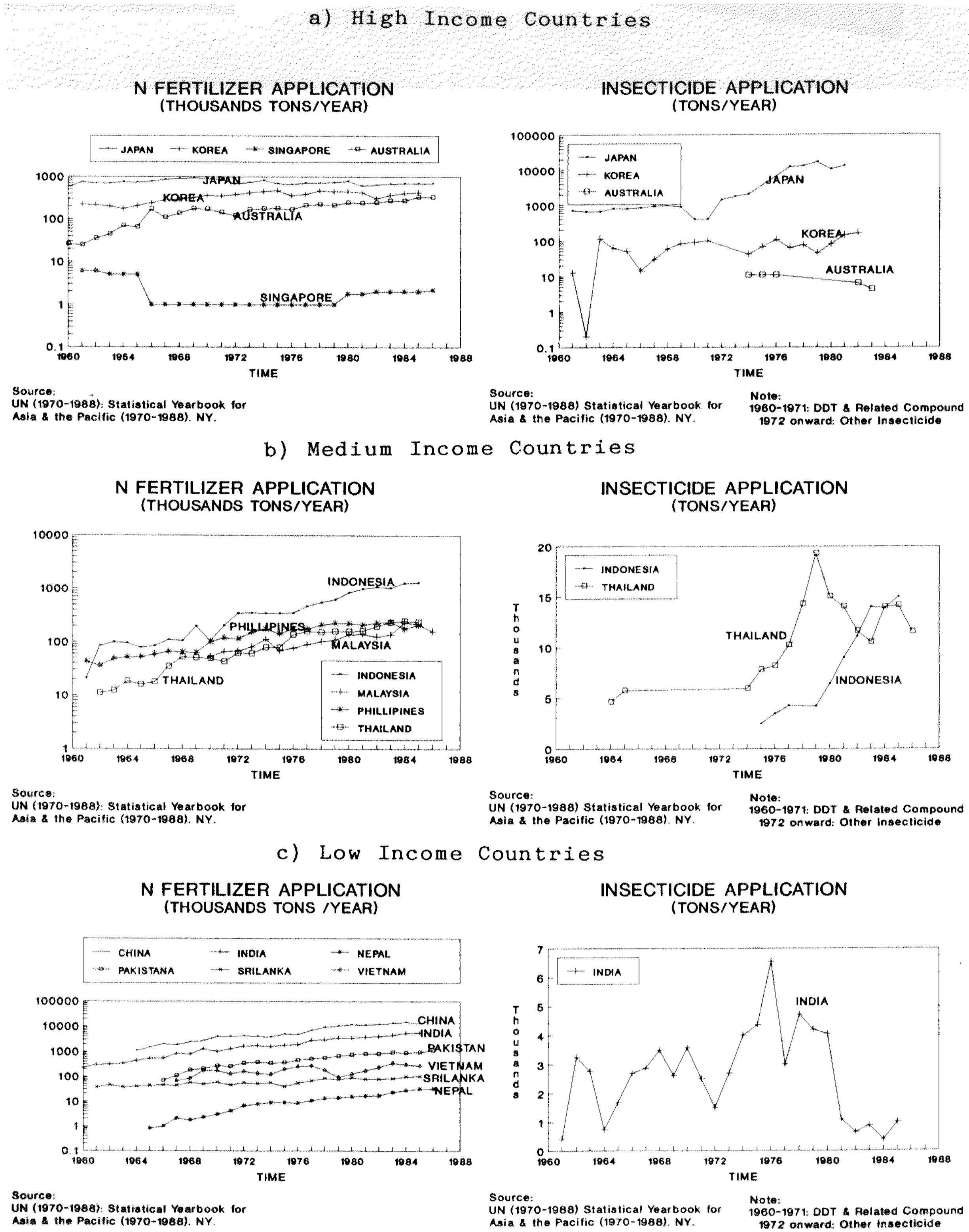
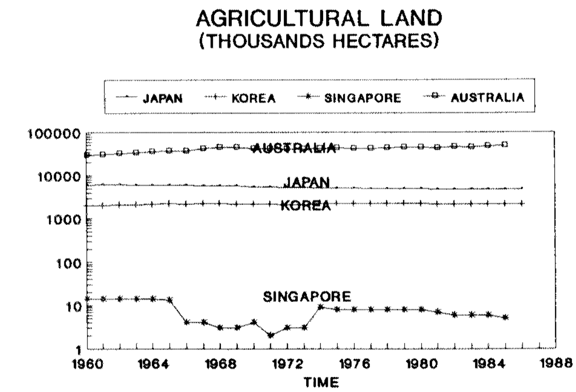


Figure 7 Fertilizer and Pesticide application

a) High Income Countries



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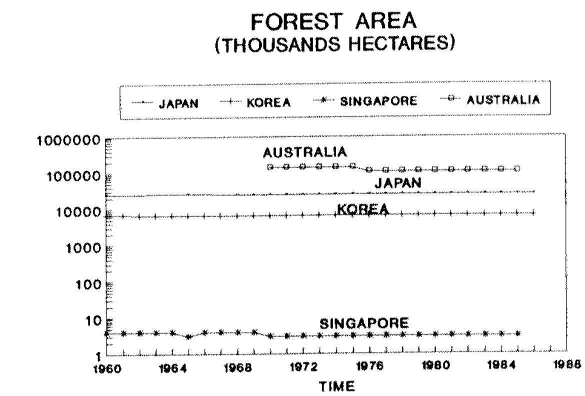

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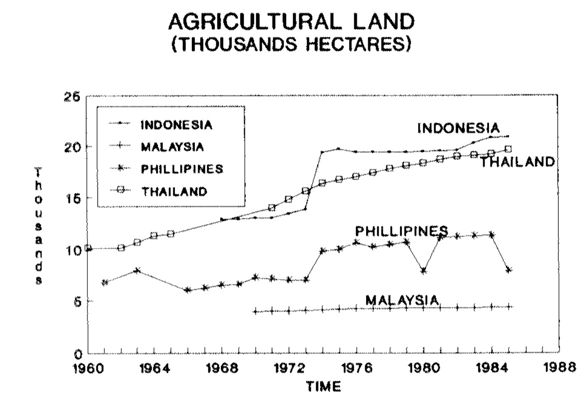
b) Medium Income Countries



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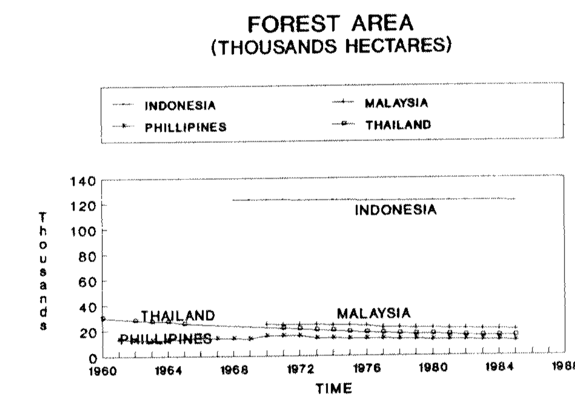

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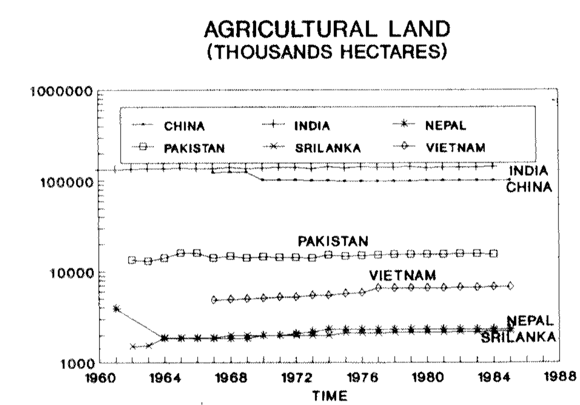
c) Low Income Countries



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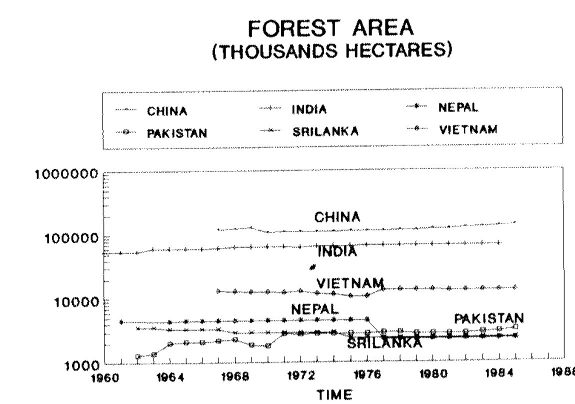

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Figure 8 The competition between cultivable and forest land

Excessive use of land resources has also been known to depreciate soil quality. Soil degradation has occurred in the countries of the sample and elsewhere because of erosion, chemical deterioration, loss of texture, water logging and salinity, all resulting from efforts to intensify agricultural activity [Bowonder 1981]. Given the over-taxing of land resources, the per capita food production index may be expected to decline in the future across the board. Declining trends have already appeared in Nepal and Bangladesh, as shown in Figure 9.

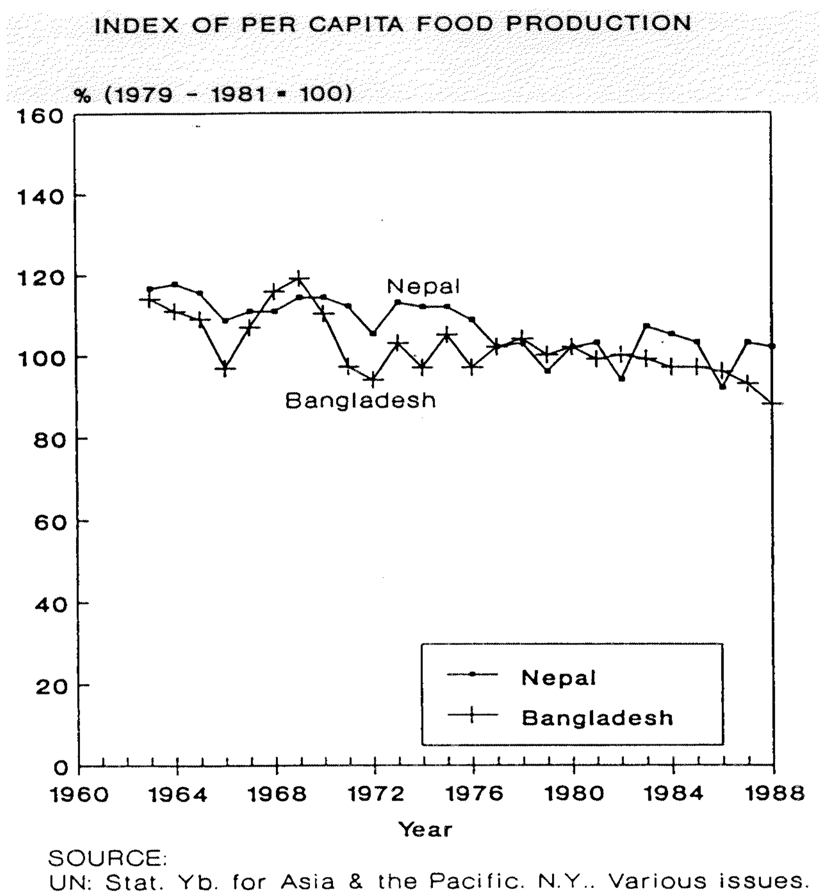

Figure 9 Declining food per capita trends in Nepal and Bangladesh

Figure 10 shows the various patterns observed in the data representing the condition of the renewable agricultural resources.

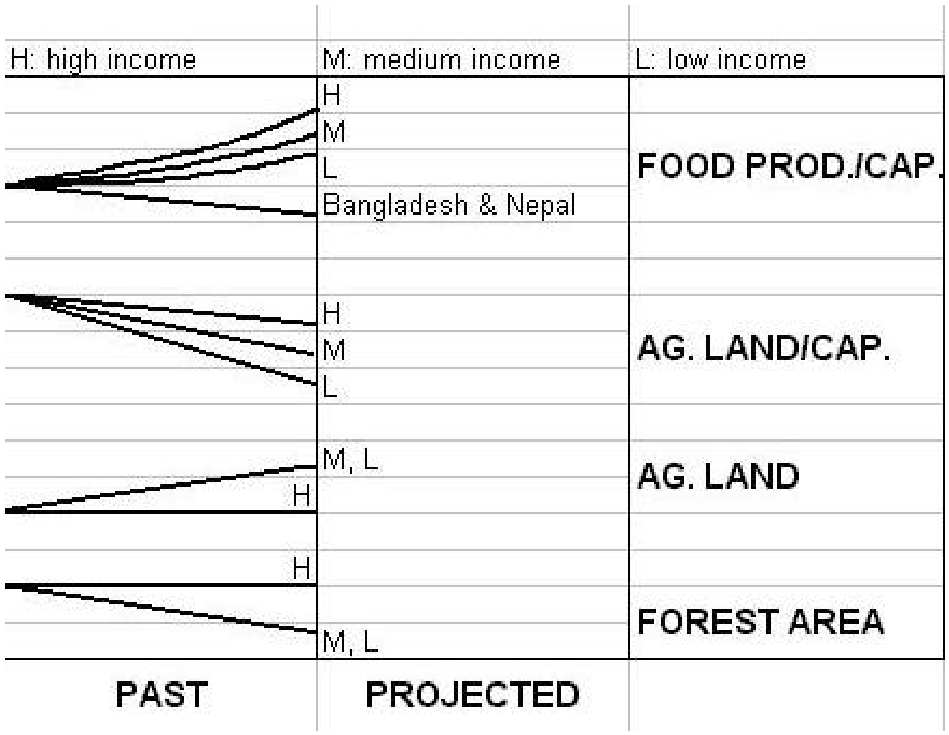

Figure 10 Graphical patterns representing the condition of renewable agricultural resources

The next step is to determine the level of aggregation of the problem and define system the system boundary. Key variables in this boundary are consumption base, which can be represented at the outset by population, the land under cultivation and inactive/unused/forest land and soil fertility for a model built for replicating the problem.

b) Recognizing past trends within the defined system boundary

After a system boundary has been delineated, past trends for variables identified within that boundary should be constructed. Figure 11 shows such trends for a model intended only for replication of the problem.

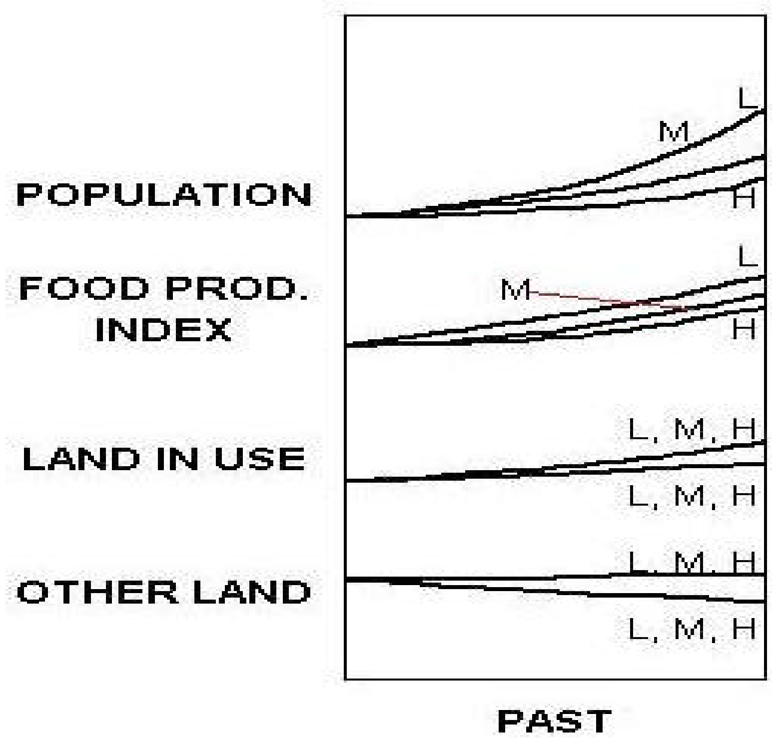

Figure 11 **Past trends representing growth of consumption base and condition of renewable agricultural resources.**

c) Constructing past trends for the policy related variables

The observed trends in the data taken from a geographically, economically and politically diverse set of countries show that in all cases, increases in agricultural production - clearly a private gain whether pursued by individuals or collectives - has been achieved in the first instance by making an intensive use of land resources viewed as capital inputs rather than as an environmental system. It is also quite evident that expansion in agricultural land has been achieved by consuming forests - another environmental system which is important to the maintenance of agricultural land as a sustainable resource, but which is viewed by individuals and collectives involved with agriculture as an unused endowment. A variable implicit in the above description is soil fertility, which is partly dependent on the volume of standing forests and partly on the intensity of cultivation. Soil fertility can be propped up by fertilizer application, but would eventually decay if the pressure on soil and deforestation continues.

A model not incorporating policy space for soil management would however not be useful for policy experimentation leading to operational agenda since it does not contain sufficient policy space for testing soil management policies. Hence additional trends must be constructed through inference using empirical and theoretical information available in soil science knowledge base. These additional trends are summarized in Fig 12

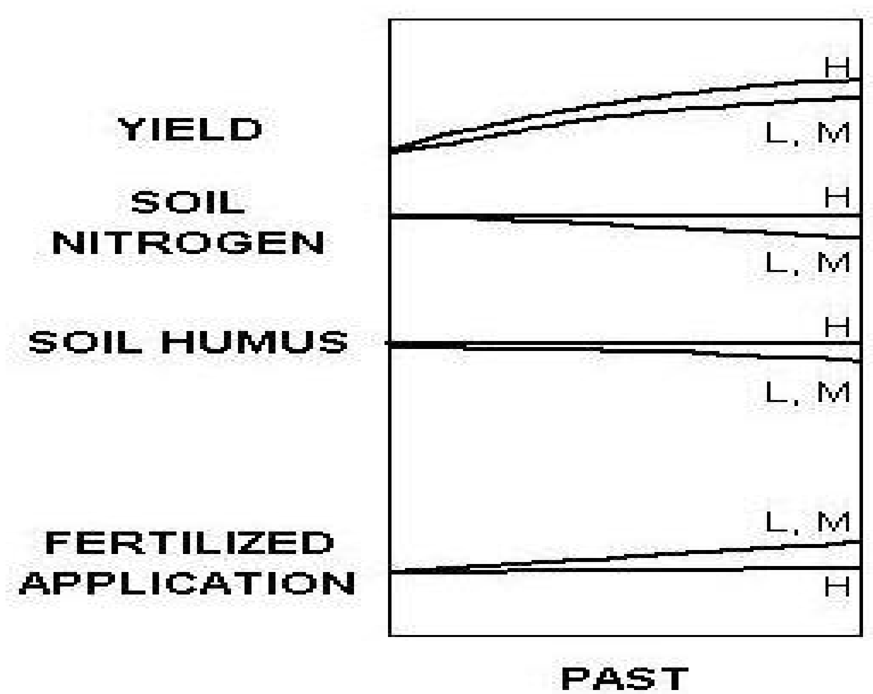

Figure 12 Additional past trends inferred from soil dynamics knowledge base.

d) Constructing the reference mode.

The projections obtained from digesting the data and policy related trends indicate an impending tragedy of the commons. The past and the projected trends portraying this pattern are shown in Figures 13 and 14. The inferred future of food production per capita shows an overshoot and decline behavior, which is followed by a similar trend in population. Land under forests and soil fertility decline to a low stagnant level and land under cultivation rises to a high stagnant level.

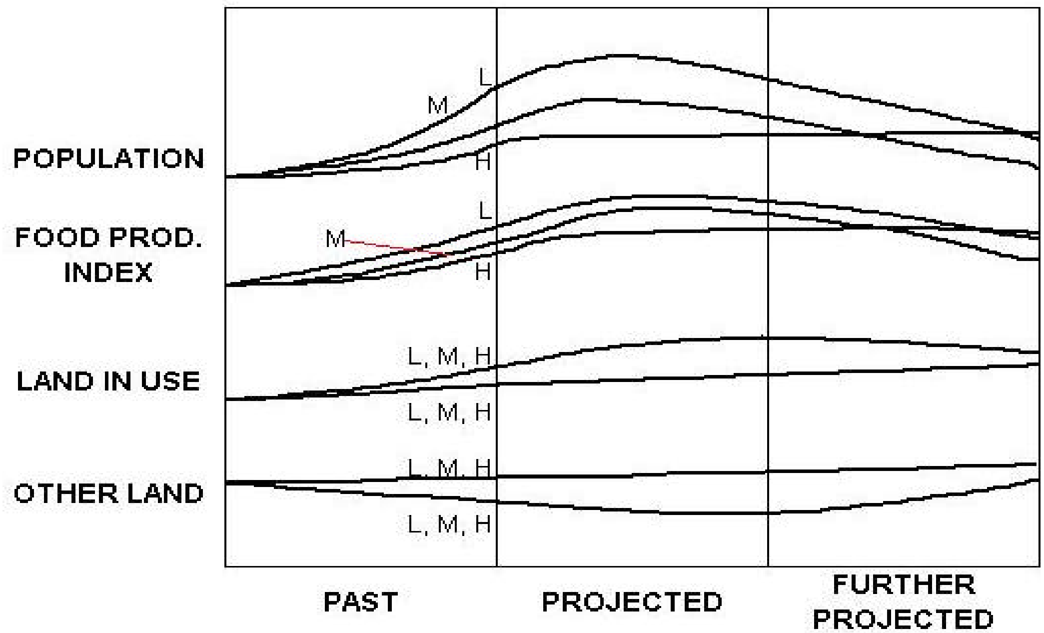

Figure 13 **Reference mode incorporating past trends and inferred projections for system variables extracted from historical data**

It should be noted that the reference mode constructed in Figure 13 represents only a slice of the complex trends indicated in data while it collects the characteristics of the 14 manifestations of those trends. It also is a pattern encompassing both past and future, rather than merely being a historical record and is based on both past history and inferred future. It contains both concrete variables appearing in the historical record and policy-related concepts like soil nitrogen, humus and yield, that sum up several pieces of quantitative and qualitative information. The time horizon of a reference mode may depend on the purpose for which a model is constructed, but it will invariably be longer than the historical record. In this case, it must be much longer than the historical record if the purpose is to search for a sustainable future as the time constants of the processes being considered are long.

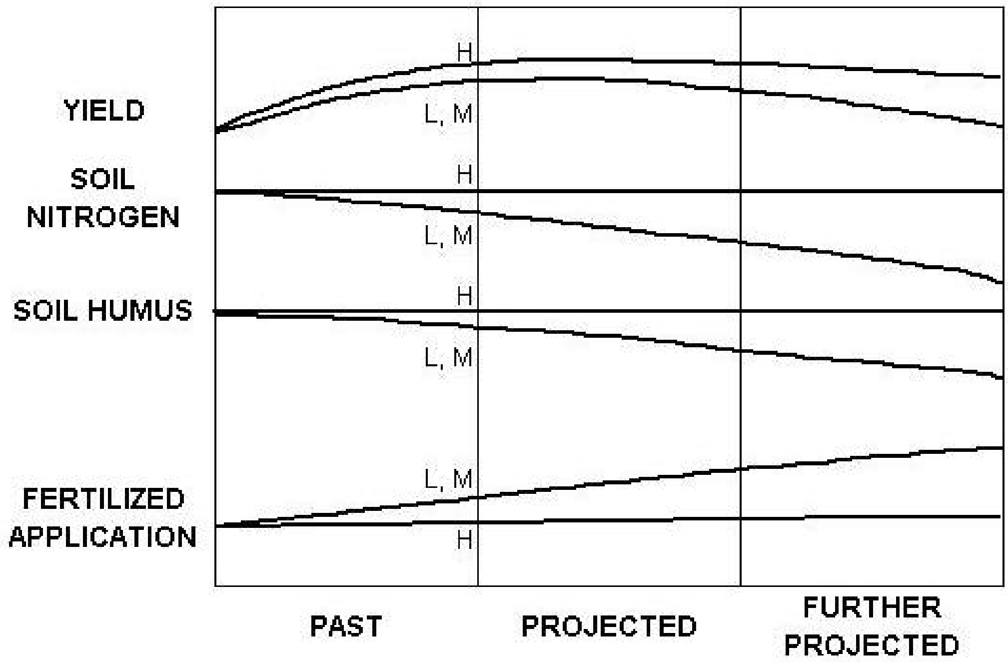

Figure 14 Reference mode components constructed from soil dynamics knowledge base to provide an adequate policy space for experimentation

A reference mode is best visualized as a fabric subsuming the trends drawn on paper and would often fall into recognizable categories of patterns, in this case - the overshoot and decline pattern describing a tragedy of the commons. This raises an important issue: why have we not attempted to recognize widely occurring patterns of behavior as reference mode archetypes? A related problem is that in a messy world, problems may not present themselves as neat archetypes, but as complex time histories.

Reference mode archetypes – a task ahead

The concept of archetypes representing generic systems pervasively found in experience is quite old in system dynamics, but somehow, the starting point for the archetype seems to have been the system structure not a problem pattern it might represent. Even the nomenclature used to define system archetypes is inconsistent. Archetypes found in the literature have been named both with respect to structure and behavior and multiple archetypes may display the same behavior. These anomalies arise apparently from not using the reference mode as a starting point for defining archetypes.

Jay Forrester has often pointed out that a small number of systems can represent about 90% of the problems encountered in experience. It is only appropriate that we attempt to define these problems in their generic form, which has been the motive behind defining archetypes.

At the outset, there seem to be three broad categories of problem behavior modes possible:

1) tendency towards a single and unique equilibrium

2) tendency towards multiple equilibria

3) patterns of growth and instability.

Within the first category, the system would tend to come to an equilibrium characterized by problems like low productivity, poor efficiency, unequal income distribution, low market share, etc. Such modes might give the appearance of a static rather than a dynamic problem, however, the points of interest in them are the end conditions *per se* but how they are reached, irrespective of the initial conditions. The second category of problems concern processes that may not lead to a single and unique equilibrium, but might display multiple equilibria depending on the inputs and the environmental conditions. Activating growth mechanisms in such systems might also transform a functional equilibrium into a dysfunctional one. The last category of problems concerns growth, overshoot and instability. Often a smooth transition to a sustainable state is desirable, overshoot and instability are to be avoided.

Further work is needed to identify specific patterns within each category that should fit pervasive problem patterns. Once the reference mode archetypes are evident, generic systems underlying them, both in terms of feedback loops and simple stock and flow structures should be delineated.

Conclusion

I have attempted in this paper to define the characteristics of a reference mode and how it is distinguished from historical data, both qualitative and quantitative. A reference mode is an abstract concept subsuming past as well as inferred future behavior. It can best be visualized as a fabric collecting several patterns as well as the phase relationships existing between them. It may contain concrete as well as abstract variables that are different from the data it is based on. It may also represent only a slice of the complex time history it emulates and may thus look very different from the history itself. A reference mode is an end product of a learning process that is similar to the process involved with building a model and analyzing it. There seems promise for constructing generic forms of problem patterns, which might fit a large cross-section of the dynamic problems encountered in the world. Constructing these generic forms is not attempted in this paper but is seen as an important part of the methodological progression expected.

References

Abbott, E. A. 1987. *Flatland*. London: Penguin

Bowonder, B. 1981. The Myth and Reality of High Yield Varieties in Indian Agriculture. *Development and Change*. 12(2).

Bowonder, B. 1986. Deforestation in Developing Countries. *Journal of Environmental Systems*. 15.

Hunsacker, P. L., and Alessandra, A. J. 1980. Learning How to Learn. In *The Art of Managing People*. Englewood Cliffs, NJ: Prentice Hall. pp. 19-49

Kolb, D. A. 1974. On Management and Learning Process. In *Organizational Psychology: A book of Readings, 2nd Ed*. Englewood Cliffs, NJ: Prentice Hall. pp. 27-42.

Kolb, D. A. 1984. *Experiential Learning*. Englewood Cliffs, NJ: Prentice Hall

Kolb, D. A., Rubin, I. M., and McIntyre, J. M. 1979. Learning Problem Solving. In *Organization Psychology: An Experiential Approach, 3rd ed*. Englewood Cliffs, NJ: Prentice Hall. pp. 27-54.

Okita, S., et. al. 1989. *The Asian Development Bank in the 1990s: Report of a Panel*. Manila: Asian Development Bank

Richardson, G. P. 1997. *Modeling for Management. Vol. II.* Brookfield, Vt: Dartmouth Publishing Co. Ch. 15

Saeed, K. 1998. *Towards Sustainable Development, Essays on System Analysis of National Policy*. Aldershot, England: Ashgate Publishing

Saeed, K. Sustainable Development, Old Conundrums, New Discords. Jay Wright Forrester Award Lecture. *System Dynamics Review*. 12(1). 1996.

Saeed, K. 1992. Slicing a Complex Problem for System Dynamics Modeling. *System Dynamics Review*. 8(3).

Saeed, K. 1992a. Asian Agriculture: A Tragedy of Commons in the Making? In David Crookall and Kiyoshi Arai (eds.). *Global Interdependence*. Tokyo: Springer Verlag

Saeed, K. 1994. *Industry and Environment in Asia and the Pacific Region*. UN-ESCAP, Bangkok

Saeed, K. 1997. System Dynamics as a Technology of Learning for New Liberal Education. *FIE conference proceedings*. Pittsberg, PA

Saeed, K. 1998. *Towards Sustainable Development, 2nd Edition: Essays on System Analysis of National Policy*. Aldershot, England: Ashgate Publishing Company.

UN/ESCAP. 1986. Environmental and Socio-Economic Aspects of deforestation in Asia and Pacific. *Proceedings of the Expert Group Meeting*. Bangkok: United Nations

UNCHS. 1987. *Global Report on Human Settlements 1986*. Habitat Nairobi: Oxford University Press