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Defining developmental problems for policy intervention
or
Building reference mode in 20 steps over 5 learning cycles

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Defining developmental problems for policy intervention,
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Abstract

Developmental problems are invariably perceived as existing conditions, which must be alleviated. This often removes a policy from the factors that created the problem in the first instance. System dynamics method requires that a problem must be viewed as an internal behavioral tendency found in a system so its causes can be determined before a corrective action is initiated. A pattern representing internal dynamics of a system, called a reference mode, must be constructed before developing a model that serves as an apparatus to create a policy design for system change. Such a problem definition process is also appropriate for understanding developmental problems such as food shortage, poverty and insurgence, so their causes rather than only symptoms are addressed by a developmental policy. A reference mode is, however, different from a precise time history in that it represents a pattern incorporating only a slice of the history and it requires several learning cycles to construct a reference mode from time history. A learning process based on a well-known model of experiential learning is used to describe the construction of a reference mode, which is illustrated at length by revisiting the problem of food shortage.

Key words: sustainable development, policy intervention, policy design system dynamics, modeling, reference mode, problem definition, experiential learning, planning.

[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 constantly urged me not to skip implicit steps in the process.

Introduction

Developmental problems are often perceived as pre-existing conditions, which must be alleviated. For example, food shortage, poverty, poor social services and human resources development infrastructure, technological backwardness, low productivity, resource depletion, environmental degradation and poor governance 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, however, that policies implemented with such a perspective not only perform variedly, they also create unexpected results. This happens because the causes leading to the existing conditions and their future projections are not adequately understood. The well-intentioned policies addressing problem symptoms only create ad hoc changes, which are often overcome by the system's reactions.

Development planning 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 snapshot of existing conditions. This behavioral tendency may represent a set of patterns, a series of trends or a set of existing conditions that appear resistant to policy interventions. In other words, an existing condition by itself must not be seen as a basis for problem definition. The complex pattern of changes implicit in the time paths preceding an existing condition would be, on the other hand, a basis for defining a problem.

The solution to a recognized problem should also 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 conceived 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 problematic patterns, provided of course a succinct representation of such patterns has first been constructed. Called a reference mode in system dynamics, such a representation is based on historical information and is often described in a graphical form. It is, however, quite different from point by point description of historical trends in that it may represent only a few selected organized patterns embodied in the complex and seemingly unorganized profile of the trends. It also encompasses both past and inferred future patterns.

Developmental policy based on recognition of existing conditions

Table 1 collects the various developmental problems and the broad policies implemented to alleviate them that one comes across in the economic development literature, although not presented as in the table. However, if one reviews the timeframes of problems and policies, the organization of the table appears to be quite cogent.

The initially perceived problems indeed were hunger, poverty and insurgence that created threats to human security. Since these problems were taken as given, the natural response to alleviate them was to facilitate intensive agriculture so more food could be produced, to foster economic growth so aggregate income could be increased and to strengthen internal security and defense infrastructure so insurgent groups could be suppressed.

The common denominator of those policies was that they attributed the existing conditions to outside factors, as if they came to be as acts of fate. They also assumed that the system is static and not self-regulating. Thus, it was expected that directly attacking symptoms would help alleviate them. Attacking symptoms without knowing how these were created of course also required powerful intervention by an outside hand and entailed an effort to strengthen government infrastructure, which in fact displaced some of the development effort. The subsequently experienced problems were many, but in most instances, these included a continuation of the existing problems [Saeed 1996, 1998].

Table 1 Developmental problems, policies implemented to address them and subsequent problems

Initially perceived problems	**Policies implemented**	**Subsequently experienced problems**
Food security	• Intensive agriculture - land development - irrigation - fertilizer application - use of new seeds	• Land degradation • Depletion of water aquifers • Vulnerability to crop failure • Population growth • Continuing/increased vulnerability to food shortage
Poverty	• Economic growth - capital formation - sectoral development - technology transfer - external trade	• Low productivity • Indebtedness • Natural resources depletion • Environmental degradation • Continuing/increased poverty
Insurgence and threats to peace	• Spending on internal security and defense infrastructure • Limiting civil rights	• Poor social services • Poor economic infrastructure • Authoritarian governance • Continuing insurgence/increased threats to peace

Thus, food shortages have continued but are now accompanied also by land degradation, depletion of water aquifers, a threat of large-scale crop failure due to a reduction in crop diversity and a tremendous growth in population. Poverty and income differentials between rich and poor have in fact shown a steady rise, which is also accompanied by unprecedented debt burdens and extensive depletion of natural resources and degradation of environment. Insurgence and threats to peace have intensified together with burgeoning expenditures on internal security and defense, which has stifled development of social services and human resources and have created authoritarian governments with little commitment to public welfare.

The subsequent problems experienced are also more complex than the initial problems and have lately drawn concerns at the global level, but whether an outside hand at the global level would alleviate them is questionable. This is evident from the failure to formulate and enforce global public policy in spite of active participation by national governments, global agencies like the UN, the World Bank, the World Trade Organization, and advocacy networks sometimes referred to as the Civil Society. This failure can largely be attributed to the lack of a clear understanding about the roles of the actors who precipitated those problems and those whose motivations must be influenced to turn the tide.

The following sections of this paper describe a learning process entailed in creating a reference mode for system dynamics modeling, which can greatly help discern developmental problems. This learning process is illustrated by revisiting the problem of food shortage. Further, the problems of poverty and internal security are redefined as manifestations of internal trends of the system rather than as acts of fate.

Reference mode construction as a learning process for defining developmental problems

Notwithstanding the assertion that the definition of a developmental problem should depend on historical trends and not on a snapshot of existing conditions, it must be understood that historical trends in their unfettered form cannot adequately describe a problem, although they might portray it a shade better than a snapshot. A succinct problem description is created in system dynamics by constructing a reference mode, which 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 or all three types. 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, qualitative information and the inferred future patterns they points to.

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 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 processes 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 demands 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 the 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]. It requires that an abstract concept be developed through a learning approach calling upon all four faculties as illustrated in Figure 1.

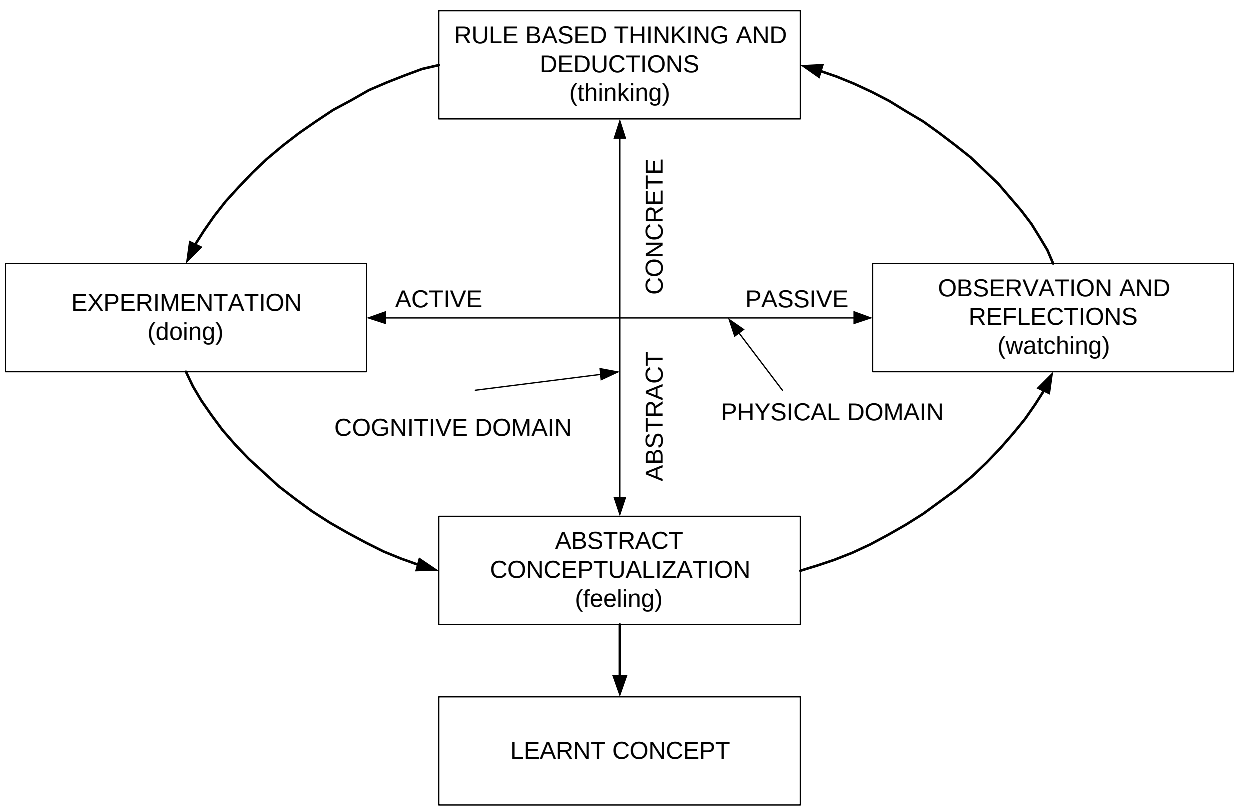


Figure 1 Kolb's model of experiential learning

Four basic faculties drive Kolb's learning cycle: 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 rule based 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 apparatus. 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. Successive learning cycles lead to the refining of the learned concept, which is the outcome of the learning process.

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 resolving the anomalies, which would appear among the constructs of each ability. This learning process lends itself with great ease to the construction of a reference mode.

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. The development of a reference mode requires integration of four abstract concepts:

1) Delineation of a preliminary system boundary.

2) Aggregation of variables in the preliminary system boundary and selection of a subset of these to determine a preliminary model boundary.

3) Insertion of missing variables (usually stocks) in the preliminary model boundary to obtain the model boundary.

4) Determination of a further extended model boundary incorporating also the policy related variables (usually flows) connected to the stocks contained in the model boundary.

5) Projecting past trends of variables in the model boundary into future to create a fabric of inter-related patterns that constitutes a reference mode. Policy variables may not be extrapolated at this stage since they are included largely to create a decision space for further experimentation.

This is accomplished through implementation of an undocumented process an experienced modeler follows. This process entails twenty steps built around five learning cycles as described below:

First learning cycle: Delineation of a preliminary system boundary

The first learning cycle that delineates a preliminary system boundary is described in Figure 2.

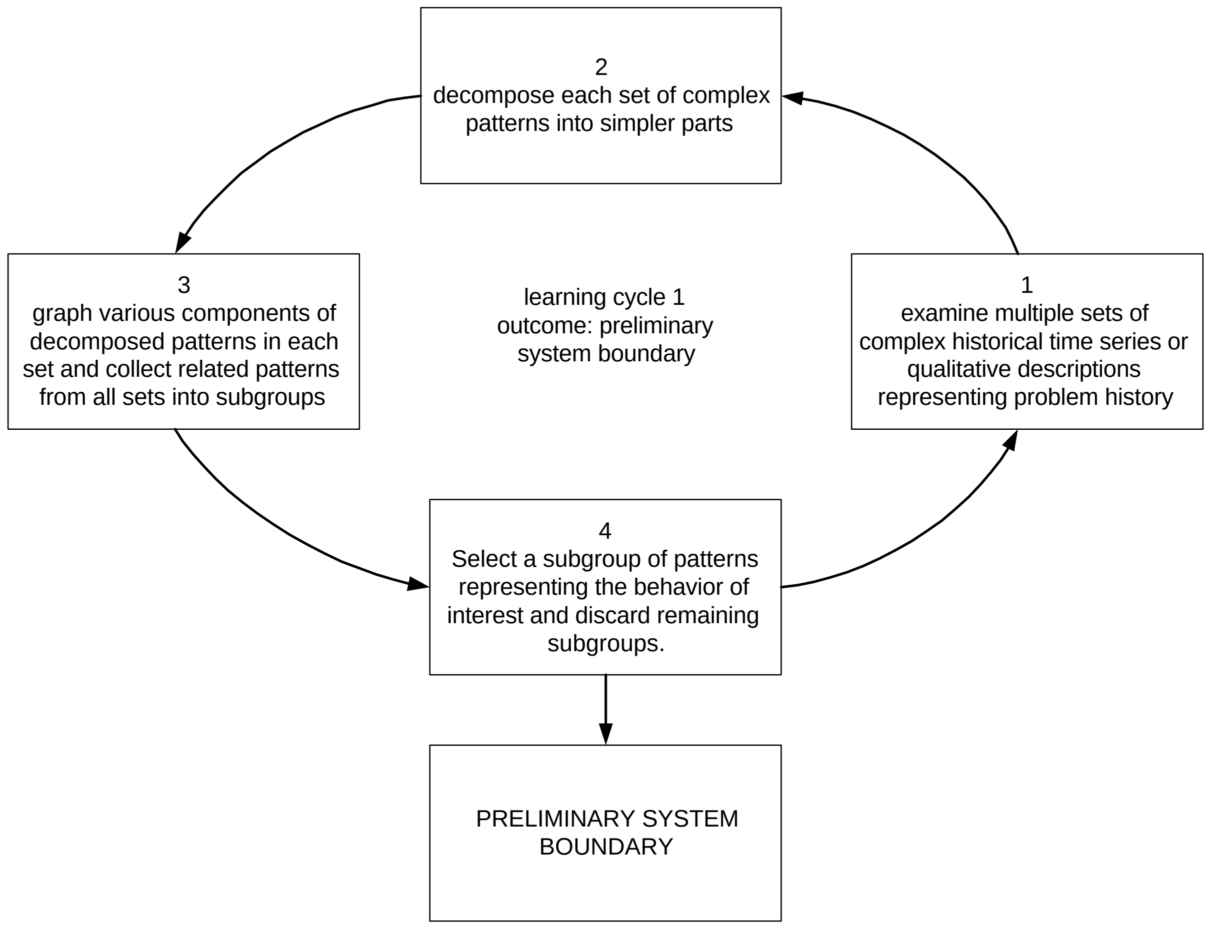


Figure 2 Delineation of a preliminary system boundary

One must begin by 1) carefully examining problem history manifest in 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. This can be accomplished either by visual examination or by using a formal decomposition process like the Fourier series analysis. 3) Next, a round of experimental graphing creates simple multiple patterns representing slices of the complex behavior one has set out to model. Related components of patterns from various times and places should be grouped together.

Figure 2a illustrates how complex time series from different times and places might be decomposed and their simpler components regrouped (Saeed 1998). 4) A careful examination of the various groups of decomposed graphs helps delineate the system boundary in terms of the variables that must be considered to describe the discerned patterns. Normally, the groups collected in columns in Fig 2a should be a part of the delineated system boundary, those in the rows can often be viewed as separate systems.

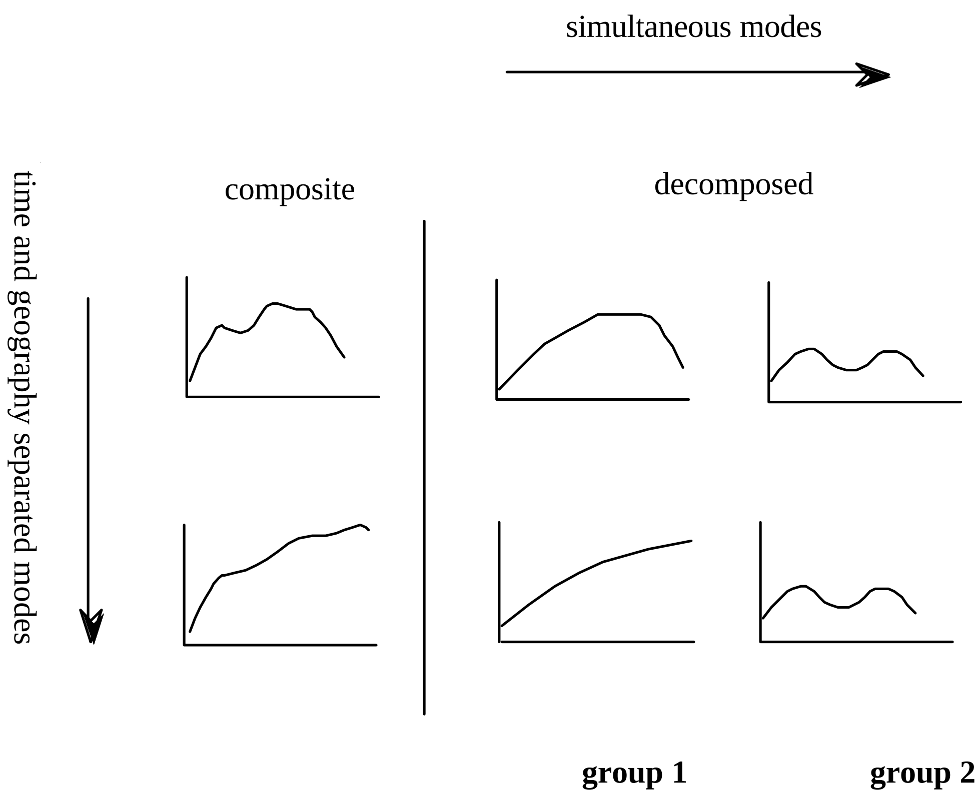


Figure 2 a **Decomposing complex time series from different times and places and regrouping their simpler parts.**

Second learning cycle: Determination of a preliminary model boundary

The model is an abstract version of the system. The variables incorporated into it would invariably be different from those in data. Some of the variables in the data will have to be aggregated to create appropriate model variables. Some of these aggregations might even create abstract intangible variables markedly different from those in the data. Some of the variables in the data might even be ignored if these are only tangentially related to the policy agenda the model is built to address [Saeed 1992]. This is illustrated in Figure 2 b.

The second learning cycle begins with 1) a careful examination of the selected group of patterns in the preliminary system boundary keeping in view the model purpose and the time horizon of interest. 2) This examination leads to combining disaggregate variables into aggregate categories and defining abstract variables not present in data. 3) A second round of graphing past trends addresses model variables as differentiated from the first round that concerned decomposing system variables and drawing trends for the decomposed parts. 4) Finally, the drawn trends are reviewed as a multi-dimensional fabric to delineate preliminary model boundary.

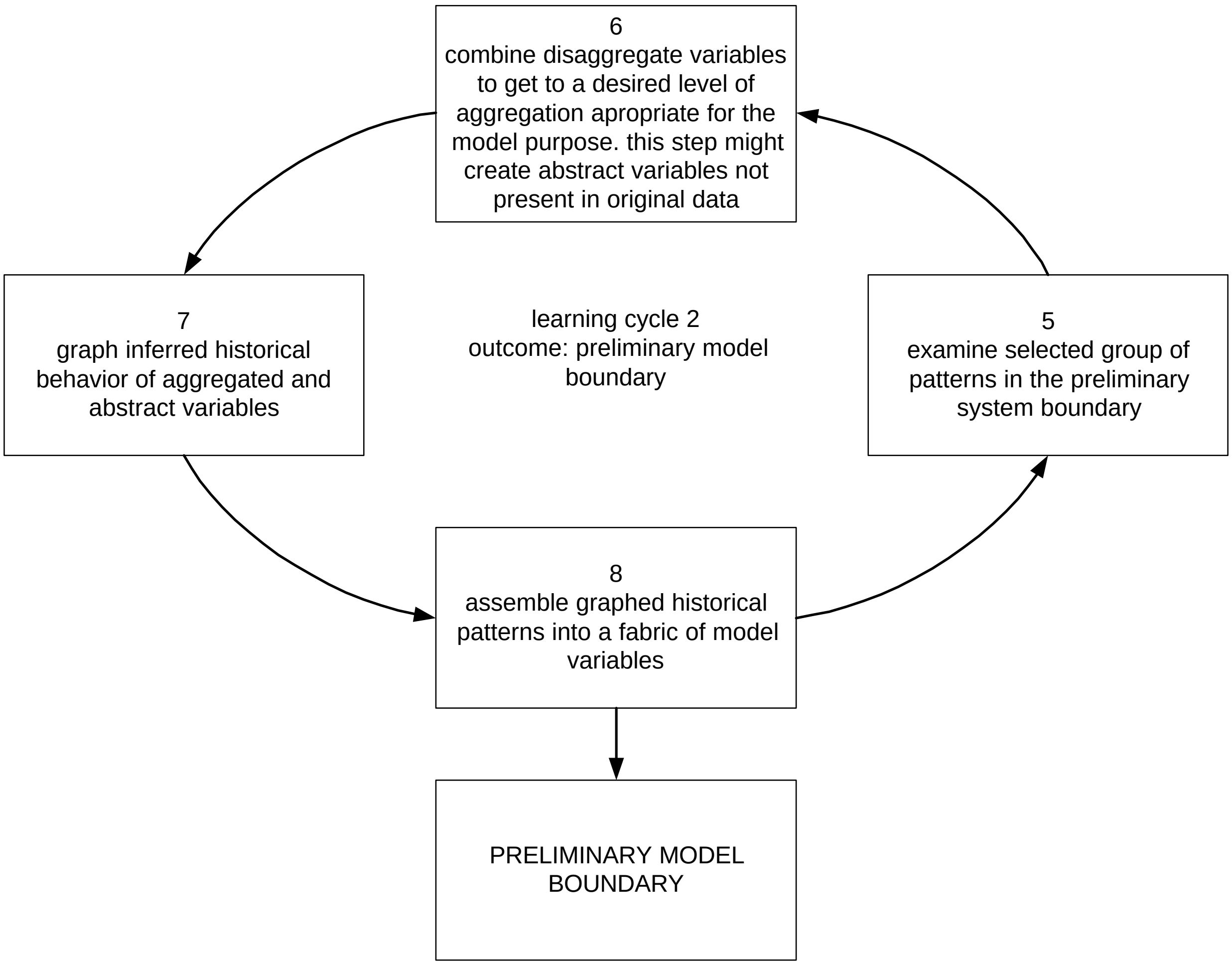


Figure 2b Second learning cycle leading to the determination of a preliminary model boundary

Third learning cycle: Extending model boundary to include STOCK variables missing in data

Not all variables in a model are captured by historical information, qualitative as well as quantitative. Often stocks that are widely distributed or hard to discern would not enter data. For example, the amount of capital stock in an economy, the amount of *in situ* resources, the level of fertility of soil, the quality of life and the amount of dissidence in a community, cannot be captured by data, although the flows related to them, respectively, production, extraction, fertilizer application and nitrogen uptake by a crop, and violent events would often be recorded. Fortunately, it is possible to discern the behavior of stocks through integration of related flows. Rules for this are well documented in mathematics and articulated in the system dynamics context in Sterman (2000). The learning cycle leading to inclusion of these stocks in model boundary is illustrated in Figure 2c.

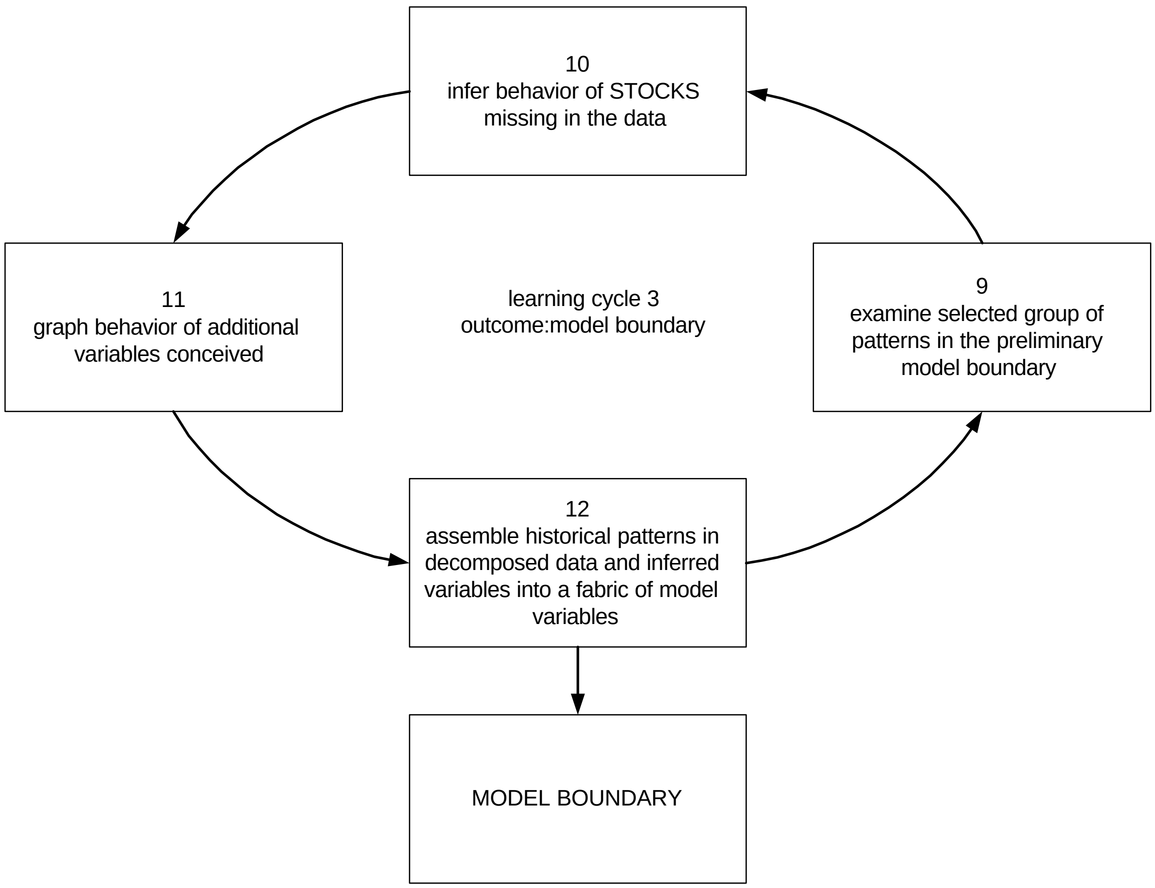


Figure 2c Third learning cycle leading to the a more complete model boundary.

The identification of such stocks must start with 1) a careful review of the trends in the preliminary model boundary in an effort to recognize flows whose sources or sinks are missing, but these cannot be believed to be unlimited or infinitely flexible. 2) This is followed by application of principles of integration to infer the patterns in the behavior of the missing stocks. 3) The inferred behavior of the newly constituted variables is drawn along side the already drawn patterns for variables in the preliminary model boundary; and 4) a fabric of variables so created is viewed as a more complete system boundary.

Fourth learning cycle: Further extending model boundary to include FLOWS representing policy variables

While a model that replicates 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, flows connected to the related stocks that are influenced by such policies should be included. If they concern delivery of certain services, the way these services are determined and how they affect existing flows or create new flows in the model should be included. If taxation and expenditure by government are possible policy instruments, the process of their determination and how they would impact other flows in the model or create new flows should be included. Construction of past patterns of behavior for the policy variables would often require going through an additional learning cycle illustrated in Figure 2d.

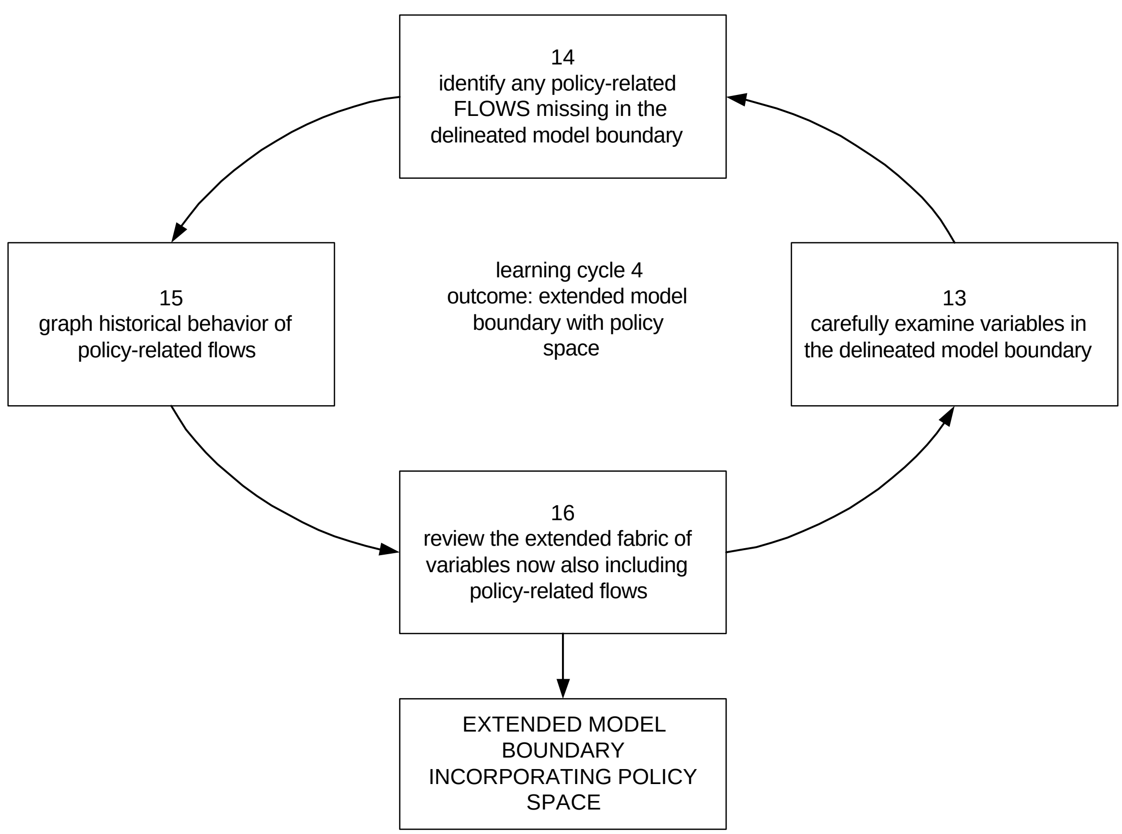


Figure 2d Extending model boundary to include policy space in it.

This cycle begins with 1) a careful examination of the past behavior of the variables in the delineated model boundary. This is followed by 2) inferring behavior of policy-related flows or influences on flows for which one might often have to delve into the empirical or the theoretical premises of the various policy threads. Next, 3) an attempt is made to graph the past patterns of behavior for the policy-related flows which when 4) combined with the already drawn past trends for the system variables create an integrated fabric of past trends representing a more complete model boundary.

Fifth learning cycle: extending past trends into the future to create a reference mode

The fifth cycle is illustrated in Figure 2e.

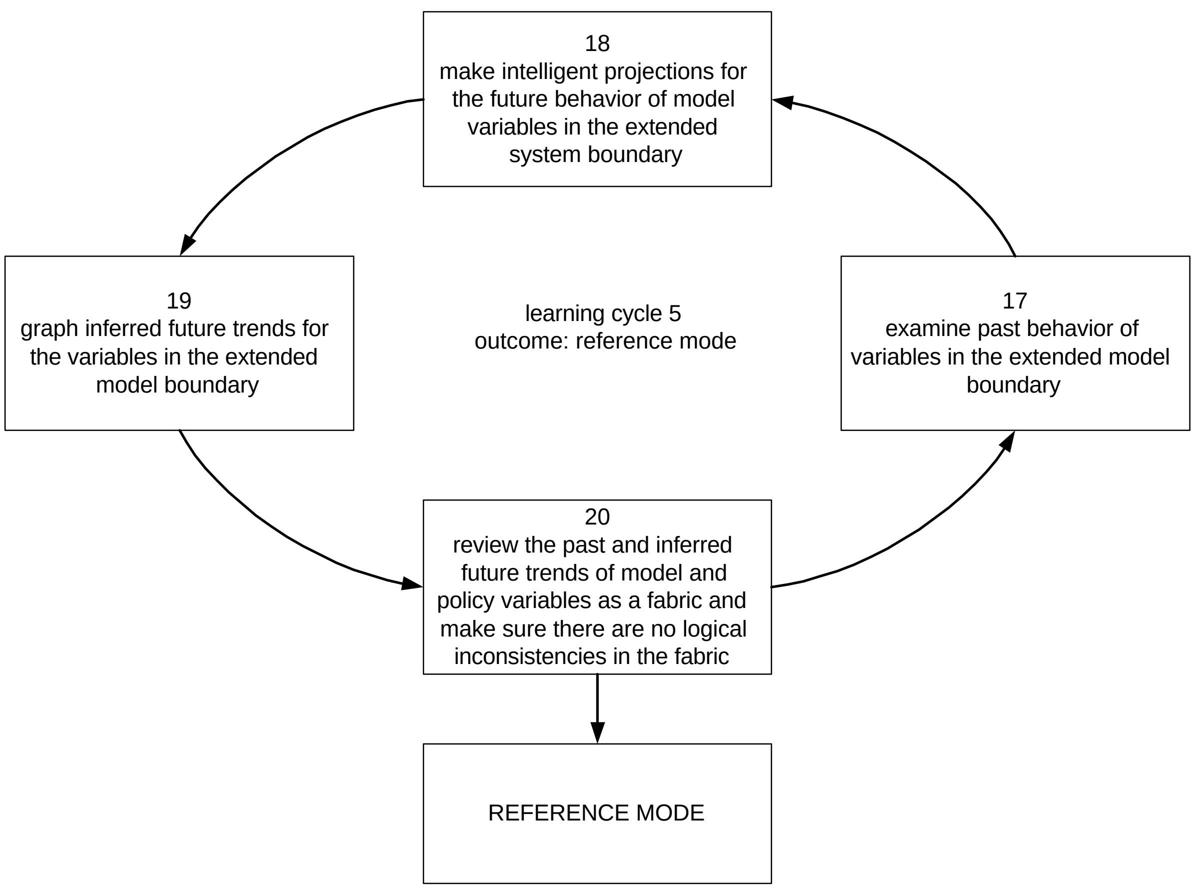


Figure 2e Extrapolating past trends into the future to obtain a reference mode

It 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. Policy-related flows may often be assumed to continue unchanged or with unchanged decision rules. 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 a developmental problem.

Above problem articulation process is illustrated with an extensive treatment of the food security problem in the next section.

An illustration of reference mode construction for the food security problem:

This section illustrates how historical data would be used to redefine the first developmental problem – food security – listed in table 1.

Historical data from selected 14 countries is a basis for determining the demand for food, food production and land use patterns in the Asia and Pacific region covering past as well as inferred future behavior following the five learning cycles described in the last section.

Some 300 time-series, covering past three decades and representing fourteen selected countries in the Asia and Pacific region, are constructed from published UN sources to serve as a data-base for the this exercise [Saeed and Acharya 1995]. There are many missing cells in the data. There are also differences in units and definitions of data categories and national policies across countries. Last, but not least, there are great differences across countries in terms of size and the volume of activity represented in the data, hence any aggregation can lead to domination of aggregate data by one or more larger countries.

The selected countries are divided into three categories based on per capita income; each category is expected to characterize a different manifestation of the problem pattern. Australia, Japan, Korea and Singapore are placed in category (A), representing relatively high levels of income. Malaysia, Thailand, Philippines, and Indonesia are placed in category (B), representing middle levels of income. China, India, Nepal, Pakistan, Sri Lanka, and Vietnam are placed in category (C), representing relatively low levels of income. This classification covers the variety of the countries in the Asia and Pacific region well, in terms of geographic location, form of government and economic conditions.

The individual differences between the data elements, in this case the country-specific time series, allow the data to be viewed as a sample representing the region it was drawn from. The countries in the various categories of the sample are not viewed as special cases, but as multiple manifestations of the behavior of the agricultural system of the region. A reference mode is constructed from above data following the process outlined in the last section. The specific steps taken are described below:

1. Determining preliminary system boundary

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

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

a) Growth of the Consumption Base

Figures 3: 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 4: 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 latter. 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 made by the United Nations, shown in Figures 5: a, b and c, tremendous growth has also occurred in urban populations across 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 that may be expected to decline further in the future. At the same time, 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 5: 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, however, 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 of population and urbanization and expansion in economic activity.

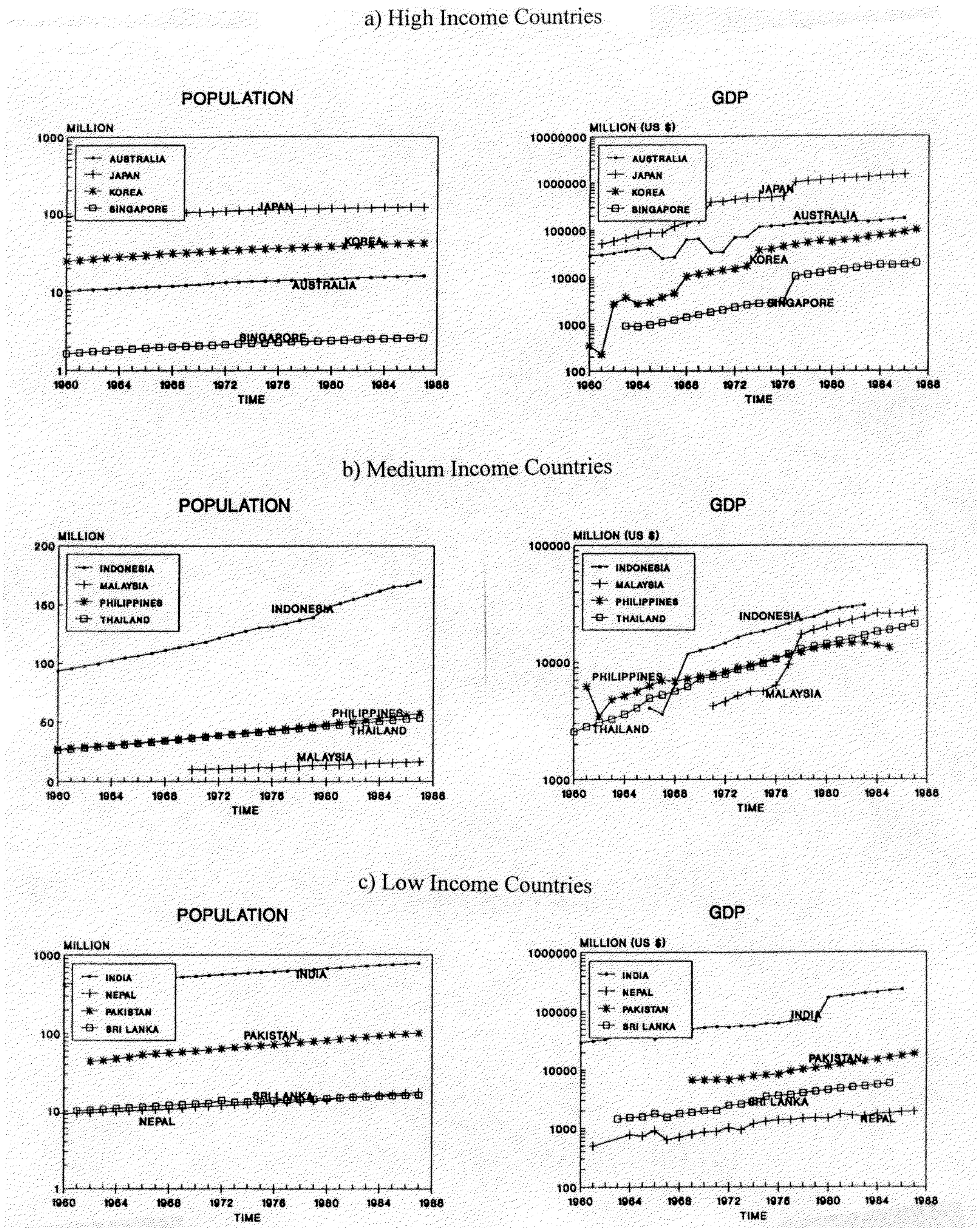


Figure 3 Population and GDP growth

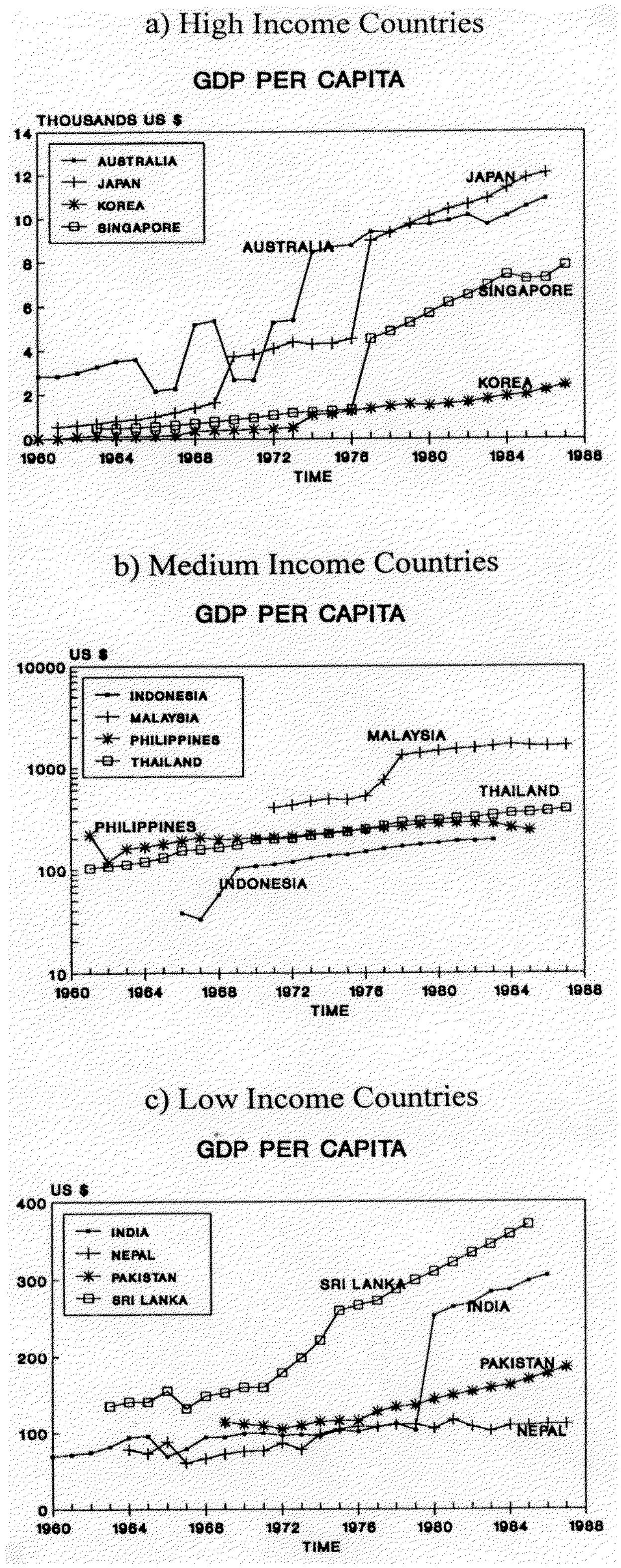


Figure 4 GDP per capita growth

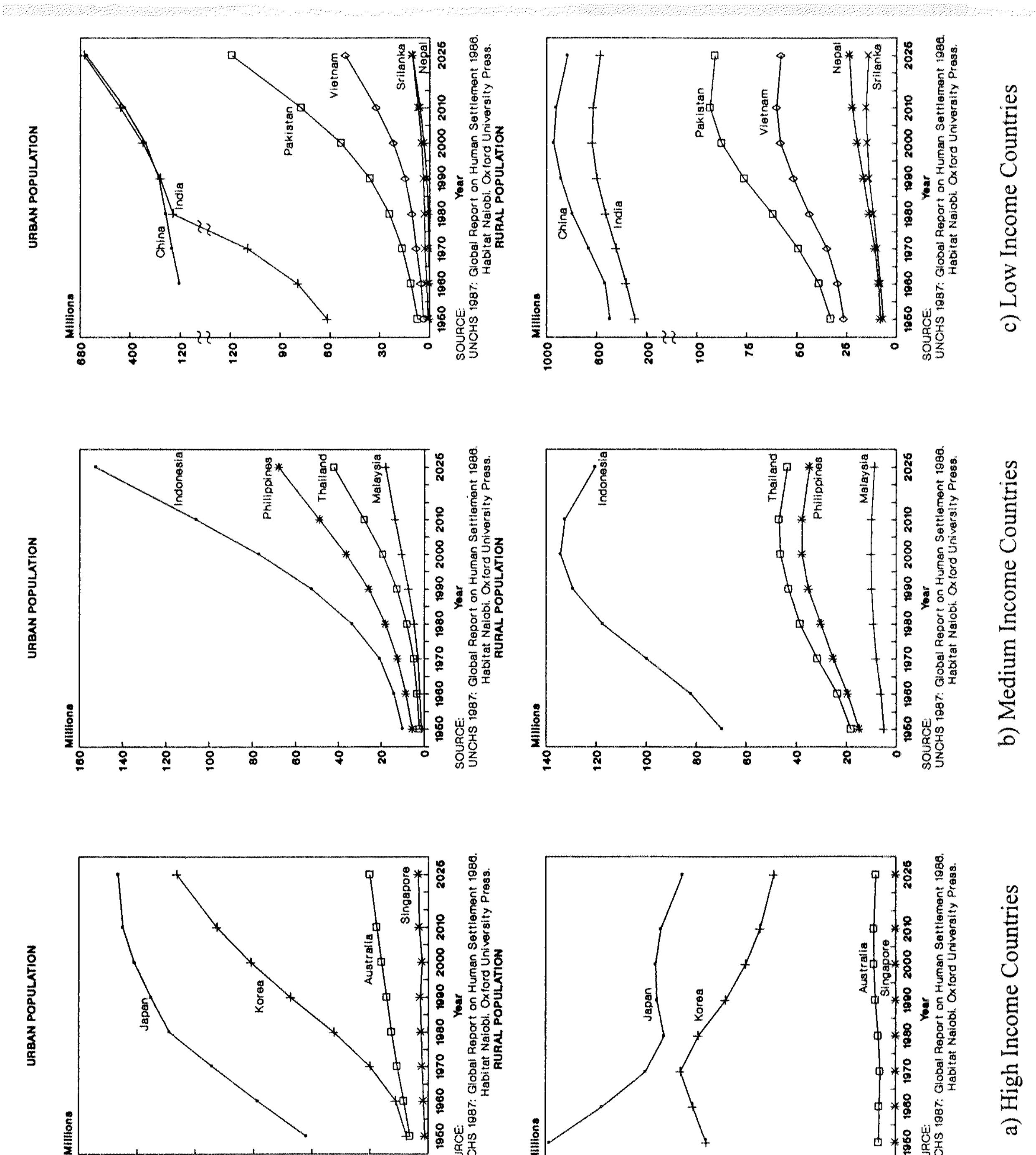


Figure 5 Projections for urban and rural population

b) 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 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.

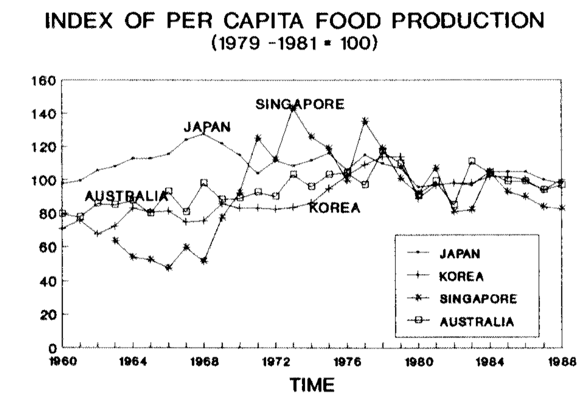
It is observed that food production per capita exhibits a rising trend in all cases in spite of considerable population growth, while agricultural land per capita shows a declining trend, except in Australia, where it has been possible to maintain it at a steady level. This indicates that increases in 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].

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.

a) High Income Countries



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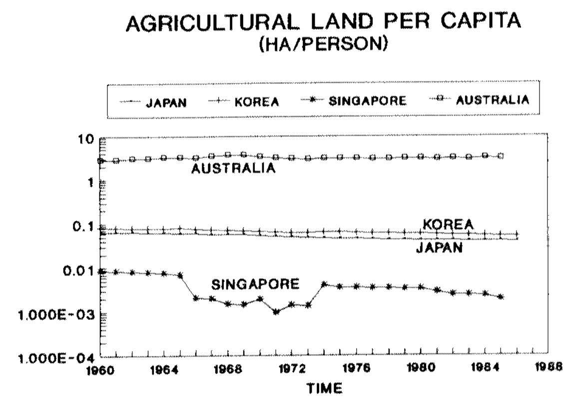
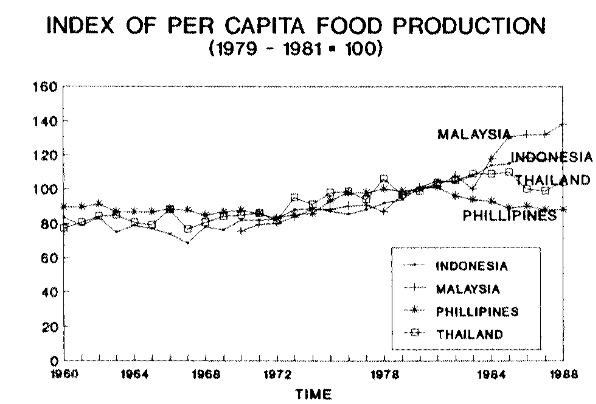
FAO 1989: FAO Quartely Bulletin of Statistics 1989. Vol.2. New York.
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.



Source:
UN (1970-1988): Statistical Yearbook for Asia & the Pacific (1970-1988). NY.
UN 1979: Demographic Yearbook 1978. NY.

b) Medium Income Countries



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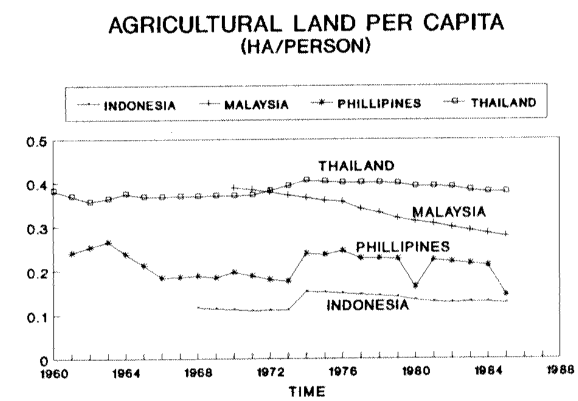

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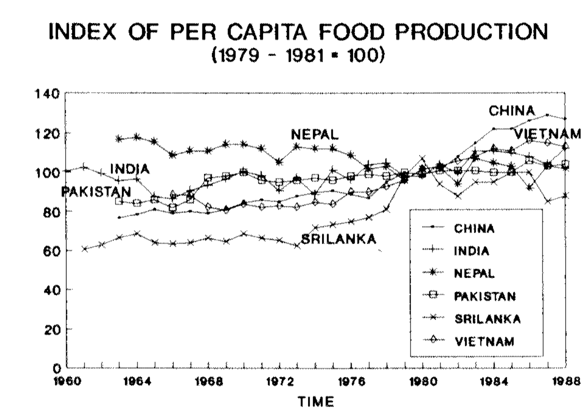
c) Low Income Countries



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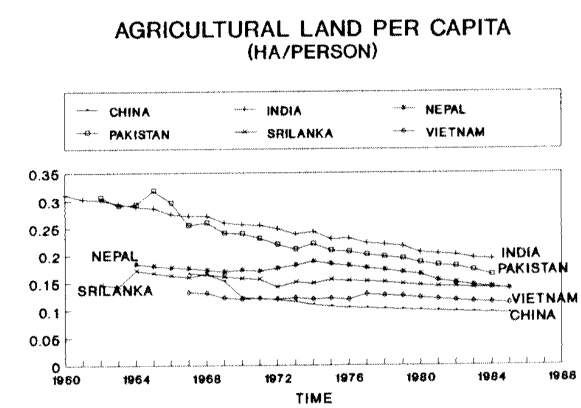

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Figure 6 Food Production per capita and agricultural land per capita

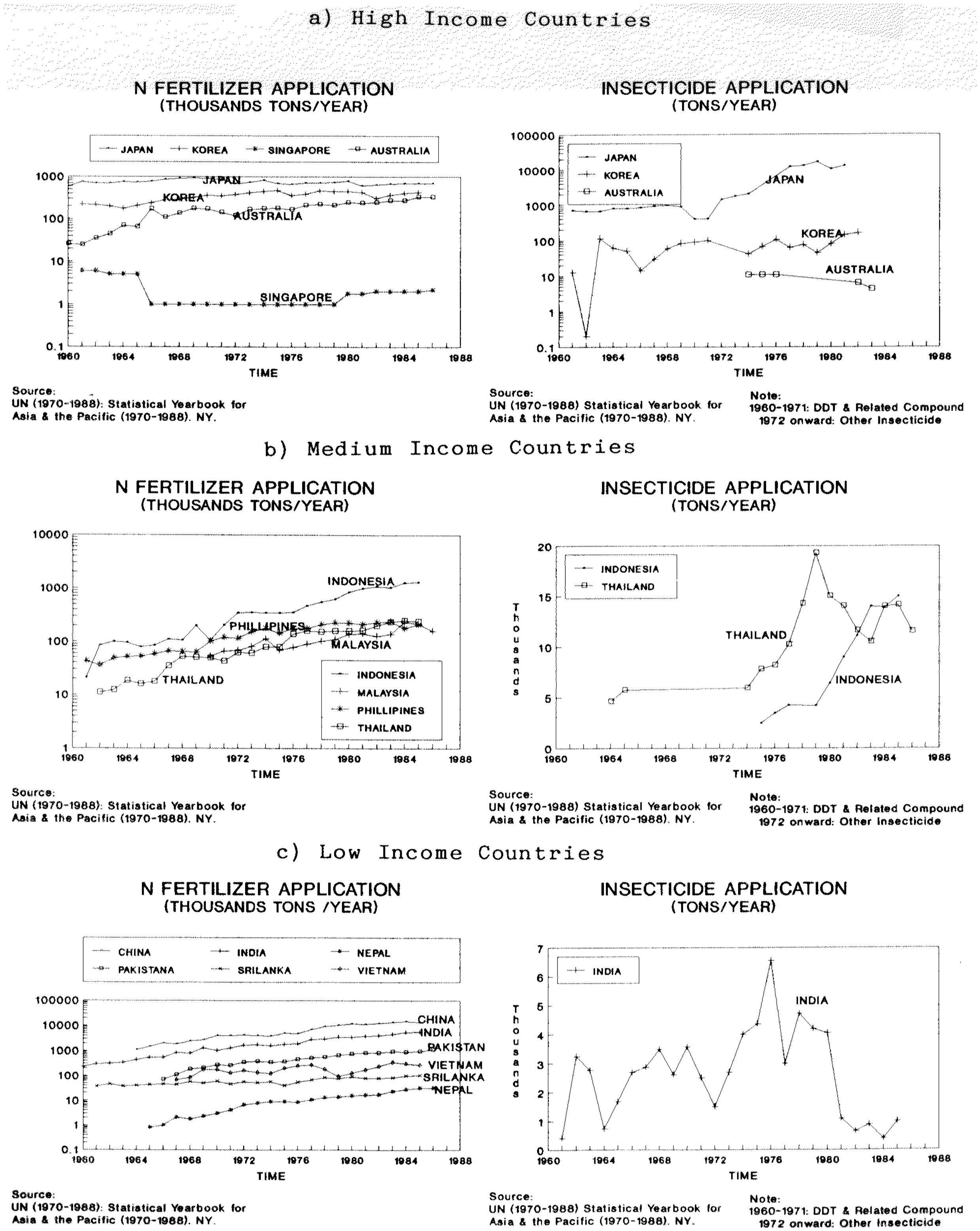

Figure 7 **Fertilizer and Pesticide application**

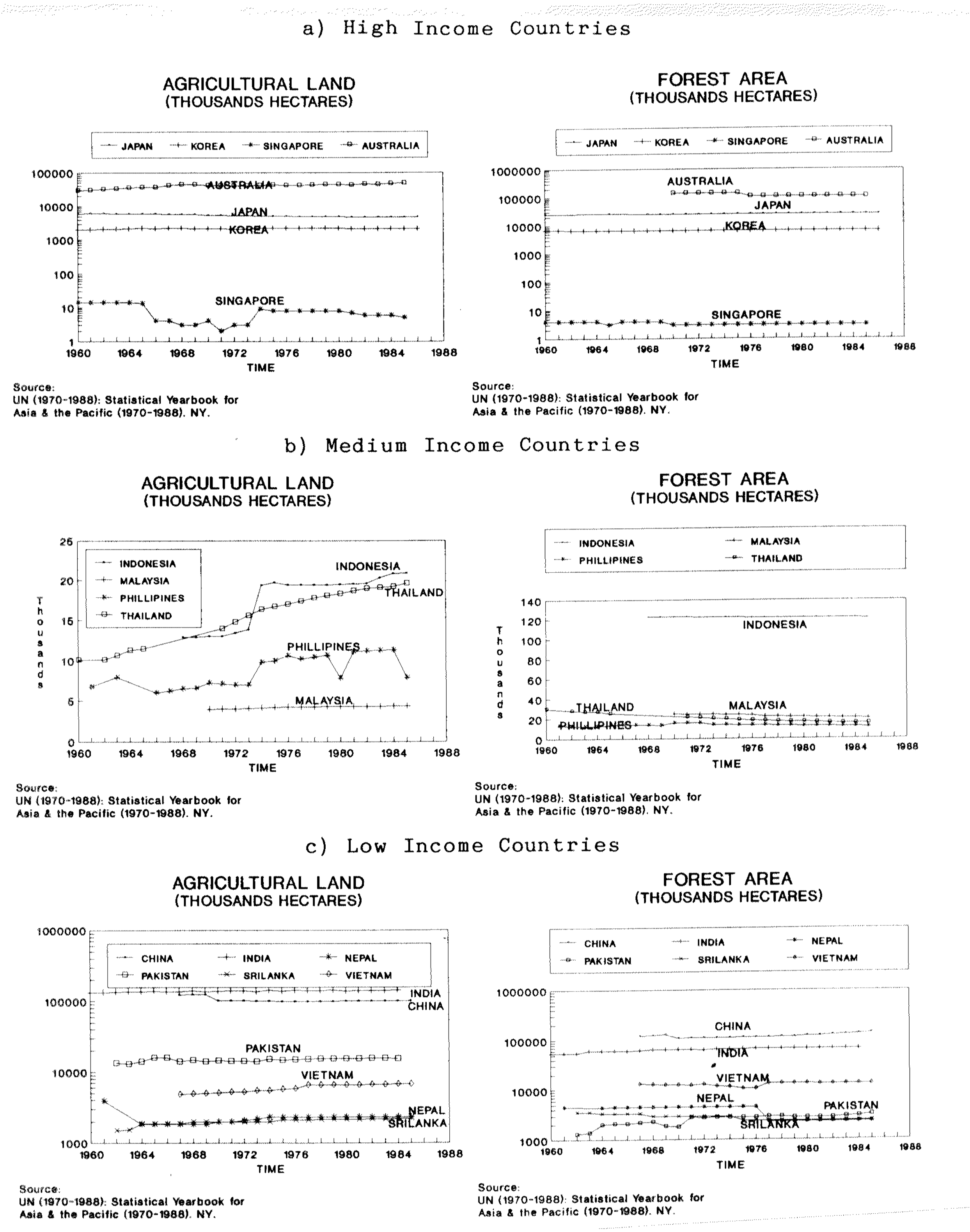

Figure 8 **The competition between cultivable and forest land**

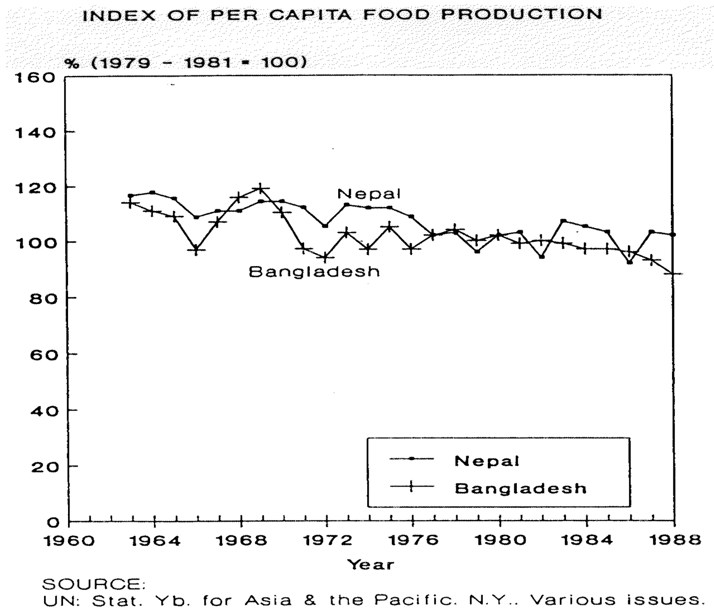

Figure 9 Declining food per capita trends in Nepal and Bangladesh

Figure 10a shows the various patterns observed in the data representing the growth of demand manifest in population (rural and urban categories are aggregated together), GDP and GDP per Capita, and the condition of the renewable agricultural resources manifest in Food production per capita, Agricultural land per capita and Forest area. Labels H, M and L pertain respectively to high, medium and low income countries. Complex patterns are decomposed into trends and periodicities superimposed on them. Trends and periodicities are drawn separately and placed in different groups for determination of a system boundary appropriate for addressing the food security problem.

The next step is to determine the system boundary. Key variables in this boundary concern both growth of demand and condition of renewable resources necessary for food production. Thus, trends representing Population, GDP, GDP per capita, Food per capita index, Agricultural land and Forest area define system boundary. Since short term fluctuations are not of concern to the long term problem of food security, the cyclical components of these trends are discarded.

2. Delineation of a preliminary model boundary

A model boundary will depend on the purpose of the model, the time horizon of interest and the policy agenda the model will address. It need not contain all the variables in the system boundary delineated above while some of the system variables might be aggregated into fewer categories. For example the source for demand for food can be limited to population if growth in income is not of interest. Food per capita, land per capita being determined by population, food and land, need not be a part of the minimum set of variables in the model boundary. Urban and rural population need not be separated (in fact, these were already aggregated together in the previous step). Thus, preliminary model boundary will consist of population, food production, agricultural land and forests as shown in Figure 10b.

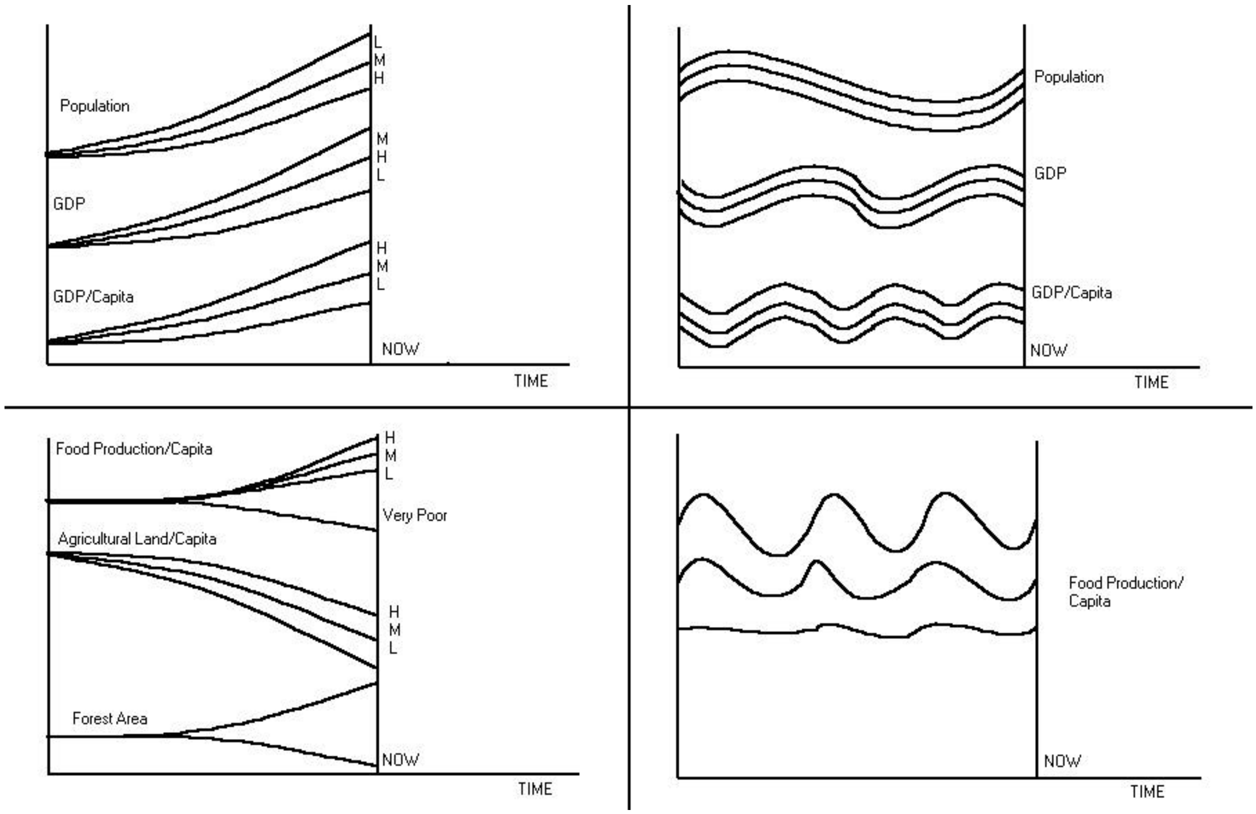

Figure 10a: Decomposition of data into patterns for delineating system boundary

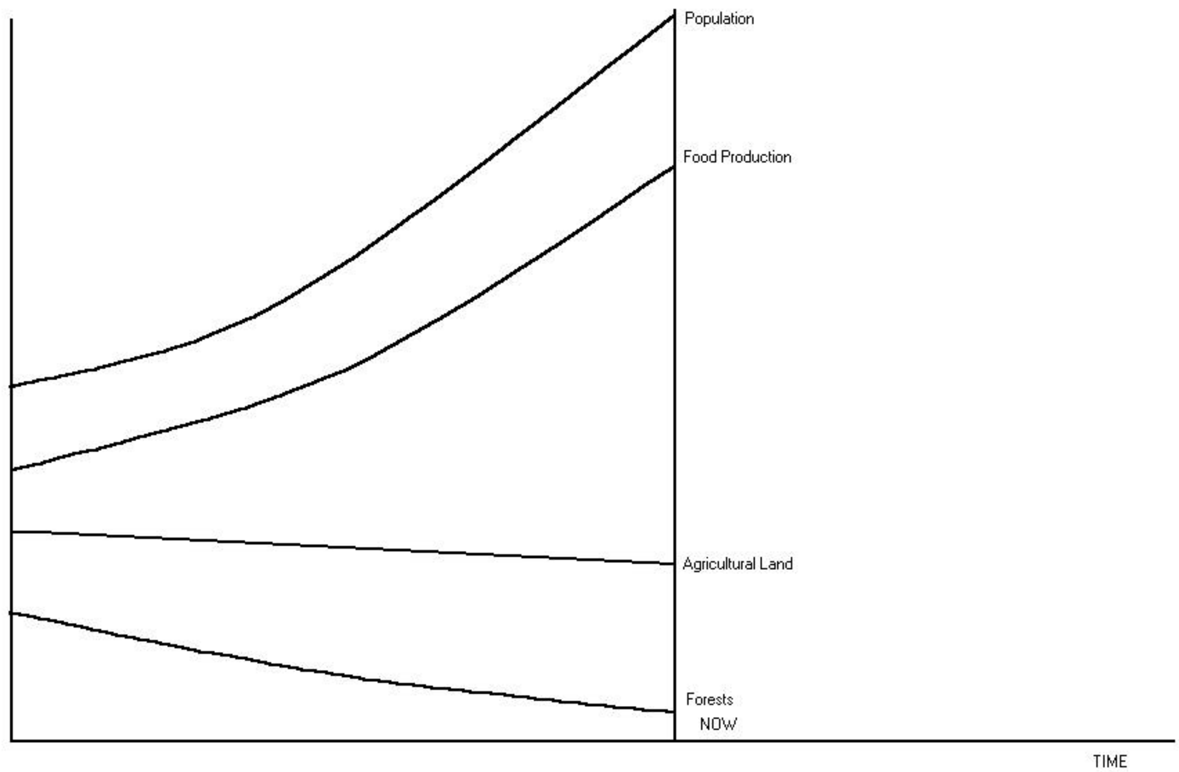

Figure 10b Delineation of a preliminary model boundary

3. Identification of missing stocks to develop a more complete model boundary

Many stocks pertinent to the purpose of the model may not exist in data, although information about these will be available in the experience domain. Thus, agricultural land when consumed is converted into wastelands. Production depends on harvest biomass, which, in turn, depends on soil nitrogen, humus, and non-harvest biomass. The behavior of these additional stocks shown in Figure 10c can be inferred from the stocks and flows existing in the data.

4. Addition of policy related flows to the model boundary

A model constructed with variables included so far would be useful for explaining the problem history identifying entry points for policy intervention, but it may not issue any operational policy instruments available within the organizational contexts it addresses. However, if flows representing policy are identified and later connected to the stocks they must regulate, policies can be constructed in terms of new and modified decision rules through policy experimentation. Hence, policy related flows must be identified at the outset when a model is built. Policy related flows in our example include irrigation, use of high yield technology, fertilizer application, land rehabilitation. The trends in these, as inferred from qualitative descriptions, are shown in Figure 10d.

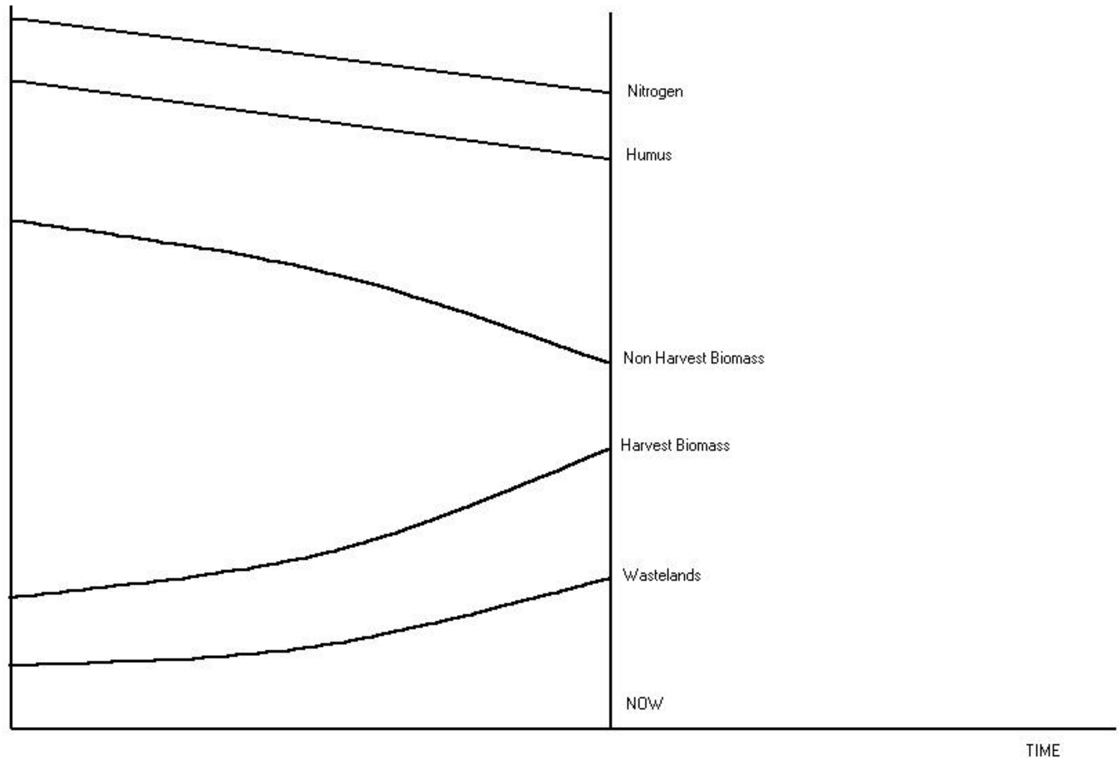

Figure 10c Determination of stock variables missing in the preliminary model boundary

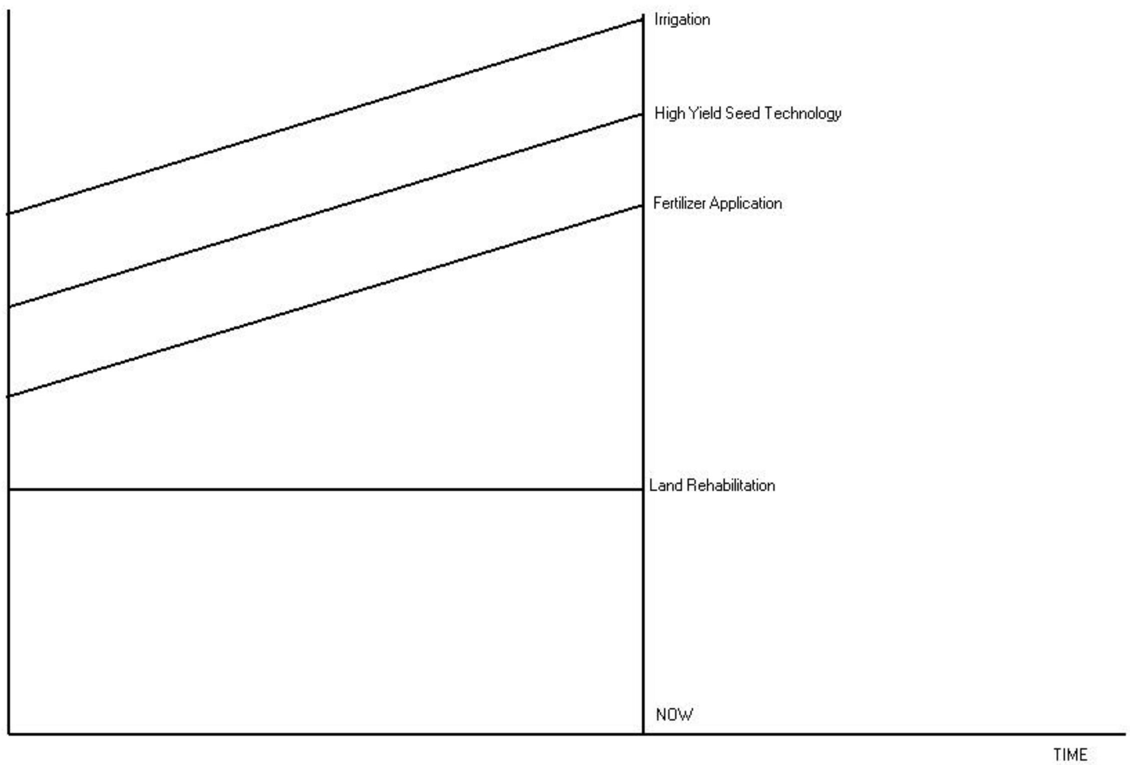

Figure 10d Determination of policy-related flows missing in data

5. Extrapolation of past trends into an inferred future to obtain reference mode

A system dynamics model has a time horizon that is often much longer than the historical information used for describing the past. In many instances, historical information inadequately describes the pattern the model must replicate. In all such instances, the delineated historical trends must be extended into the future. In our example, a threat to food security is not indicated in historical information but appears when historical trends are extrapolated into future. It is evident that food production cannot grow in the face of shrinking agricultural land, increasing wastelands, declining forests, and decreasing soil nutrients and humus. This is shown in Figure 10e, which illustrates the reference mode for a model that should be built and experimented with to explore robust policies for creating food security.

It should be noted while the patterns in Figure 10e are carefully digested as a fabric that the trends in the data taken from a geographically, economically and politically diverse set of countries show increases in agricultural production in all cases - clearly a private gain whether pursued by individuals or collectives. It is also evident that the increases in production have 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 [Saeed 1992a].

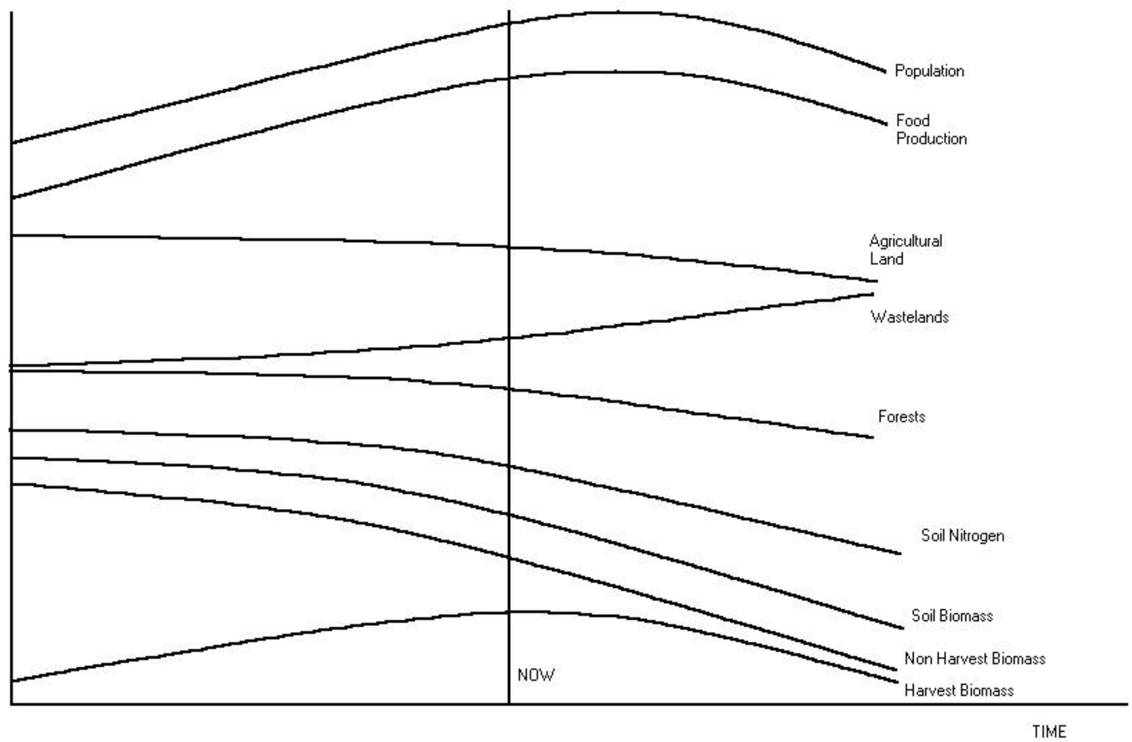

Figure 10e: Extrapolation of past trends into future to obtain reference mode

The projections obtained from digesting the patterns contained in the reference mode indicate an impending tragedy of the commons in which food production per capita will overshoot and decline, followed by a similar trend in population. Land under forests and soil fertility will decline to a low stagnant level and land under cultivation rises to a high stagnant level. It is also evident that land use management and soil rehabilitation are important parts of policy agenda that must be explored by the model.

6. Reference modes for poverty and internal security problems

Reference modes for describing internal trends towards poverty and insurgence and threats to security can likewise be constructed. Since a historical record of variables describing poverty is difficult to obtain, the internal trends towards poverty can be understood by examining the past efforts to alleviate poverty and the system tendency to restore the original patterns. The patterns shown in Figure 11 and 12 have been constructed following above learning process, but using pertinent information relating to poverty and political instability. Figure 11 illustrates how real wage rate has stagnated after an initial increase following the commencement of developmental effort while GDP rose and the production by formal firms replaced self-employment.

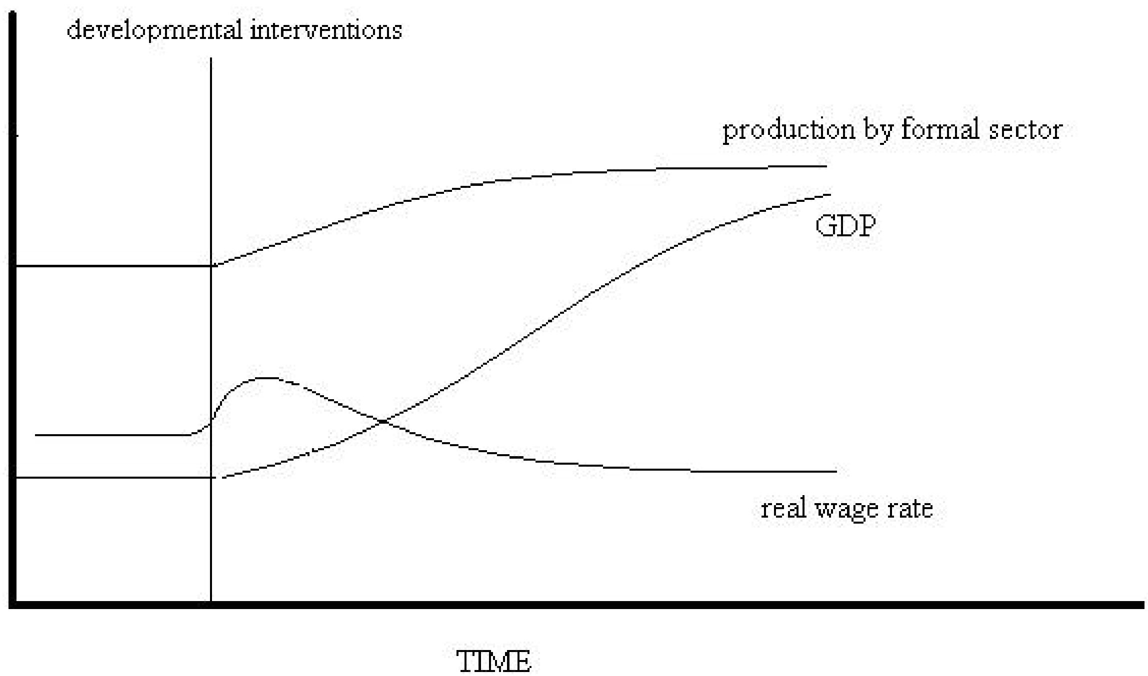

Figure 11 A reference mode constructed to describe the problem of widespread poverty

Figure 12 shows how insurgence and internal security and defense budgets rose concomitantly with national income when developmental interventions occurred. Some scholars even suggested on the basis of an observed high correlation between growth of income and growth of internal security and defense expenditure that the latter was a means to achieve the former. Subsequent experience showed, however, that economic growth could not be sustained along with increasing spending on defense and internal security and all three graphs must turn down although with a specific phase relationship with respect to one another as also shown in Figure 12.

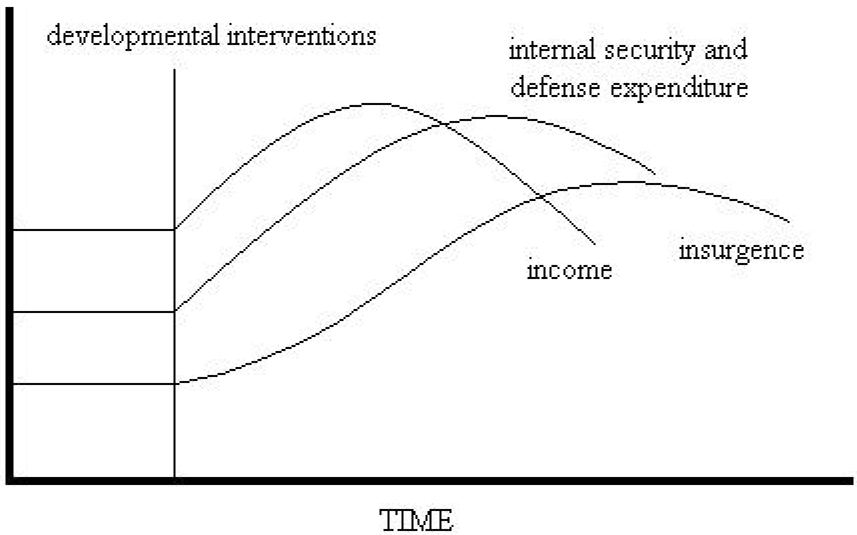

Figure 12 A reference mode constructed to describe the problem of insurgence

7. Current developmental issues

As the global economic system becomes highly integrated, concomitant methodological advancements have no doubt also greatly increased our ability to understand the increasingly complex problems of sustainability. However, both formulation of developmental policy and its implementation now involve actors and institutions operating beyond national boundaries, which makes it exceedingly difficult to converge on shared perceptions of both problems and the roles and responsibilities of the various local and global organizations. This has led to much controversy. Table 2 lists the key actors involved in the formulation of development policy and their performance expectations from the various local and global organizations they are trying to influence.

These key actors consist of global agencies like the World Bank, the World Trade Organization, the various developmental agencies of the United Nations and European Union and the various regional strategic and trade alliances. They also include national governments, the public and a relatively new actor – the non-government advocacy organizations often referred to as the civil society. These actors bring different goals and different mental models about the sources of problems to the formulation of national and global policies.

Table 2 **Key actors and systems they try to influence in present day developmental agenda**

Systems	System performance expectations of various actors			
	Global agencies	***National government***	***Civil society***	***Public***
Global economy	Grow	Change in structure	Support special interests	Create opportunities
National economy	Maintain	Grow	Support special interests	Deliver welfare
Production units	Compete	Generate tax revenue and foreign exchange	Support special interests	Provide meaningful employment
Natural resource system	Sustain global interests	Support national growth	Be nurtured	Support living standard

The various systems whose performance is influenced include the global economy, the national economies, the production units and the natural resource system, albeit with different expectations. Thus, the global agencies would like the global economy to grow but without any structural change. This means that the national economies must maintain their existing position in the global system, while production units compete to deliver a larger output. Of course, the resource system must accommodate the aggregate performance expectations without disrupting the current consumption structure.

The national governments require the national economies to grow and to accommodate this the global economy to change in structure. They expect the production units to generate enough tax revenue and foreign exchange so burgeoning national security and defense needs are met and national debts are serviced. They also expect to exploit their natural resources, which includes logging tropical rain forests and burdening pristine resort environments as much as possible to accommodate growth.

The civil society organizations expect all global, national and local production systems to accommodate the various special agendas they attempt to articulate while the natural resource system is preserved and nurtured. Finally, the public expects that the global economy will create new opportunities for them, the national economy will deliver welfare, the production units would provide meaningful employment and the natural resource system would support an improvement in their standard of living.

Unfortunately, this variety of expectations combined with an even larger variety of perceptions about how the different systems function has led mainly to controversies and anomalies instead of generating any effective policies. In particular, global public policy that mainly concerns trade and environmental agenda has been difficult to formulate and implement due to disagreements among the proponents of free trade, economic efficiency, responsibility for environmental cost and fair trade.

An attempt to carefully define problems through construction of reference modes, building system dynamics models around defined reference modes and experimenting with the models to design developmental interventions can deliver effective public policy for implementation both at local and global levels. It can also help the actors involved in policy formulation to converge to a shared view of the developmental problems through the learning process involved in problem definition and modeling processes.

8. Conclusion

Developmental problems can be succinctly defined by constructing a reference mode representing the patterns of behavior preceding an observed problematic condition. 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 policy design based on experimentation with a model that is closely tied to a reference mode has promise to be effective.

The process of constructing a reference mode and building a model based on it can be as important as the model itself. This process assists people to identify their assumptions and test their beliefs and assertions. In this way, it generates dialogue between system participants. Since the model can represent different insights and points of view in an objective fashion, it provides a relatively neutral language and framework to help reveal critical issues in a shared framework.

Implemented over the course of a negotiation, the system dynamics modeling process is invaluable for creating a shared vision leading towards a resolution that is based on the logic of the problem rather than on the adversarial views articulated during the negotiation. A logic-based mitigation process elicits greater commitment and cooperation on the part of parties than an adversarial process based on different mental models of problems.

A system created in a given developmental context can be studied by translating known and inferred experiential information into a model and experimenting with it prior to formulating the terms of a policy. Developing international policy accords requires dealing with complex relationships and diverse perspectives that create unforeseen future system behavior if one relies only on the often limited mental models of policy makers. Bargaining based on existing power structures often results in terms that are unfair and that create unresolvable future conflicts and security threats. Experimentation with a system dynamics model, on the other hand, allows all parties to develop a common perception of the problem and recognize future implications of decisions, which should help in the design of robust accords and reliable system performance.

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