Agricultural Land Use and Food Security in Asia:
Green Revolution and Beyond

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Abstract

This paper reviews the patterns of growth in agricultural production and land use existing in Asian countries and how they are affecting agricultural resources and food security. A comparative analysis of time series data from a variety of Asian countries is used to discern the past trends for food supply, agricultural resources and the growth of consumption base. Future trends of those indicators are inferred by employing a pattern recognition process used in defining problems for systems analysis. A system dynamics model of the underlying causal relationships is then developed and experimented with using computer simulation. The analysis illustrates that agricultural resources are being overstrained and the continuation of the policies causing this may precipitate a widespread decline in agricultural production across-board, thus threatening food security. The technological solutions to this problem may exist, but these will be ignored unless social and institutional reforms are introduced to create the incentives for adopting sustainable agricultural practices. The general directions for these reforms are outlined and the problem solving perspective adopted in this paper extended to address other developmental agenda.

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Introduction

Agricultural land use policies adopted in the Asian countries to increase agricultural output have indeed created what is known as a green revolution. Unfortunately, while they have increased food production across board, they have not created any lasting improvements in food security. In fact, these policies have precipitated trends that point towards an impending decline in food production. As much as they represented a well-intentioned effort to improve food supply for indigenous use and agricultural output for export, these policies were implemented without intimately understanding the societal and ecological dynamics that precipitated a condition of shortage in the first place.

This paper analyses published time-series data from a cross-section of Asian countries with a systems perspective to illustrate the patterns of changes taking place in the agricultural resource base of the region. The underlying trends indicate that while the consumption base has expanded across board through increases in population and income, food production has increased largely through intensive cultivation and agricultural land resources have mostly stagnated. In some instances, agricultural land under cultivation has increased, but at the cost of a reduction in forest land.

The paper also translates the characteristic relationships underlying the interaction between agricultural management policies and the ecological mechanisms of the agricultural resource system into a system dynamics model. Experimentation with this model shows that a sharp decline in agricultural production may be expected across the board unless sustainable agricultural technologies are adopted. Unfortunately, sustainable agricultural technologies, even when available, will not be put into practice as long as the technological and economic considerations governing agricultural policy remain divorced from environmental information concerning land resources and soil ecology. Short-term private gains in production will be sought at the cost of the decay of the common resource system that sustains agriculture. Thus, an institutional framework needs to be created, so that appropriate ecological information becomes a regular basis for the economic decisions leading to appropriate technological choices.

The problem with agricultural land use in Asia

A problem is often perceived in a conventional sense as an existing condition, which must be alleviated. For example, in the economic development context, poverty, unequal income distribution, food shortage, high illiteracy rate, low infrastructure inventory and corruption are often defined as problems. In a business context, low market share, overstaffing, poor quality, low productivity, non-profitability, etc., are viewed as problems. In all such cases, the starting point for a policy search is the acceptance of the existing condition defined as the problem. In a systems framework, a problem is defined as an internal behavioral tendency found in a system. 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 is not deemed adequate as a problem definition. The complex pattern of change implicit in the time paths preceding this end condition would, on the other hand, represent the problem.

The pattern of trends representing the agricultural land use problem articulated in this paper was prepared by the author some time ago for the United Nations Economic and Social Commission for Asia and Pacific (UN-ESCAP) [Saeed 1994]. Some 300 time-series, covering fourteen selected countries representing the Asia and Pacific region over the past three decades, were constructed from published UN sources to serve as a data-base for discerning past trends.[1]

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[1] Data taken from Statistical Yearbooks for Asia and Pacific. 1988, 84, 80, 78, 77, 76, 74, 72 and 70. New York : UN Publications; World Energy Statistics 1950-64. New York : UN Publications; Quarterly Bulletin of Statistics. 1989. FAO; Environmental Data Report. 1987. UNEP; Demographic Yearbook 1978, 1979. New York : UN Publications; World Resources 1987. New York: World Resources Institute; World Population Prospects. 1988, 1989. New York: UN Publications.

There were many missing cells. There were also differences in units and definitions of data categories and variability in the national policies across countries. Furthermore, there existed a large variety in the size of the economies, therefore, data from one country could dominate an aggregate trend. Hence, it was decided not to aggregate country data into any regional categories but to examine closely the selected set of countries as many manifestations of a renewable resource system.

The selected countries were divided into three categories based on a classification proposed by the Asian Development Bank [Okita 1989]. 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; while China, India, Nepal, Pakistan, Sri Lanka, and Vietnam were placed in category (C) representing relatively low levels of income. The last category is dominated by SARC countries and hence is a representative sample of multiple manifestations of trends in the SARC region. The presence of China and Vietnam in this category allows comparison across countries with similar land use and economic level, but with different sizes and governance systems. The presence of different categories allows comparison across countries with different economic conditions.

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. These plots end in 1987, but this does not limit the quality of inference since this data is used to construct patterns that extend beyond the time series end points. Indeed, more recent data corroborates our inferred projections [World Resources Institute Website 2000]. Agricultural land use was examined through a per capita food production index, fertilizer and pesticide application, cultivable land and area under forests. Additionally, related patterns pertaining to soil quality and fertility were constructed from soil science knowledge base. The following observations were made with respect to the growth of the consumption base and the condition of agricultural land.

Growth of the Consumption Base

Figures 1: 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 2: 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.[2] 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 3: 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 3: 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 - lower income countries experiencing higher and continued rates of total population growth and urbanization [UNHS 1987]. In all cases, there is growth in the consumption base originating from two sources, growth in population and expansion in economic activity.

[2] All monetary data has been converted to US dollar equivalents. Food Production indices based on 1979-81=100. Some of the time series required unit conversions and reconciliation of contradicting numbers. In all cases, more recent numbers were preferred over the older data. Some of the missing data cells were computed through interpolation between existing entries.

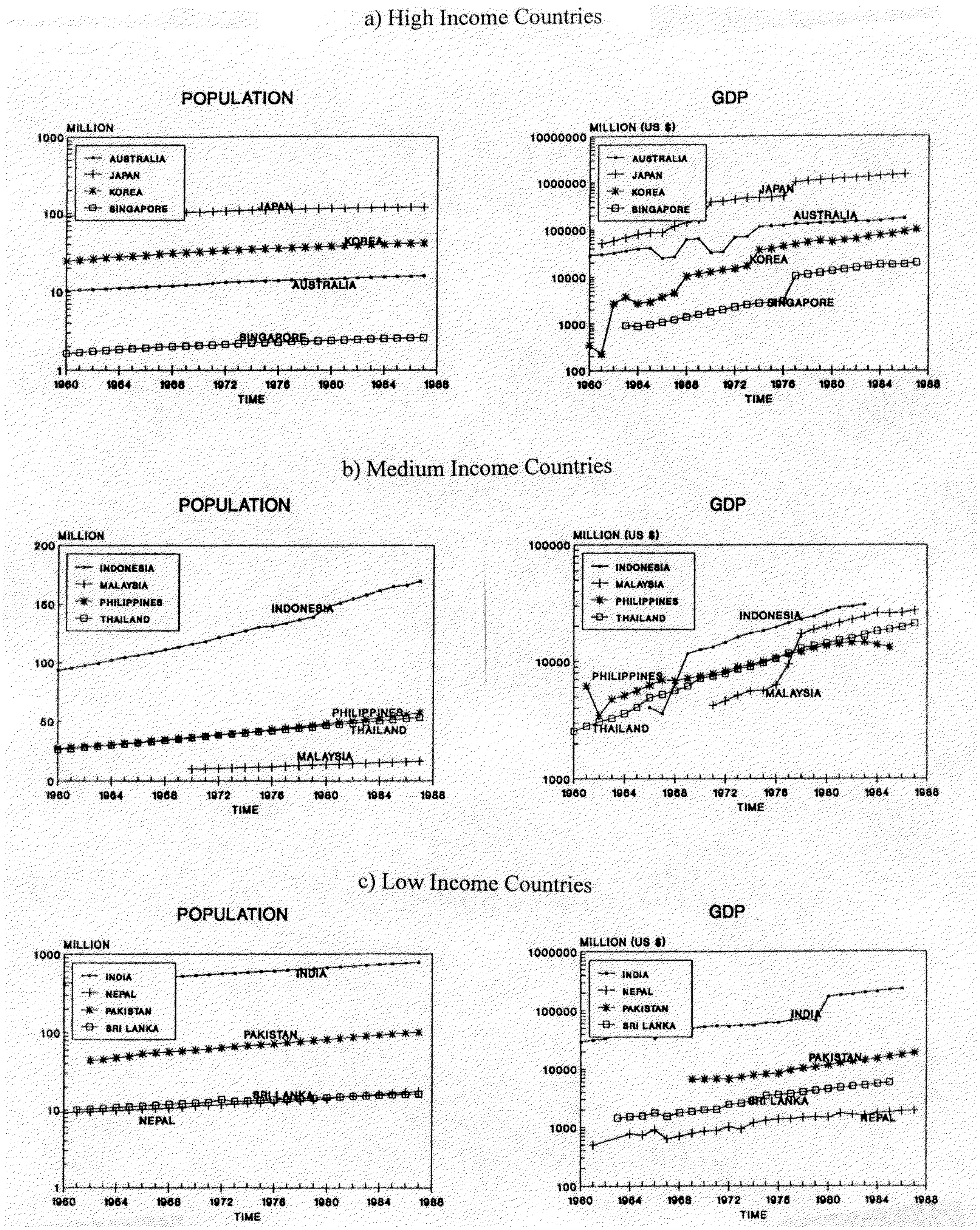


Figure 1 Population and GDP growth

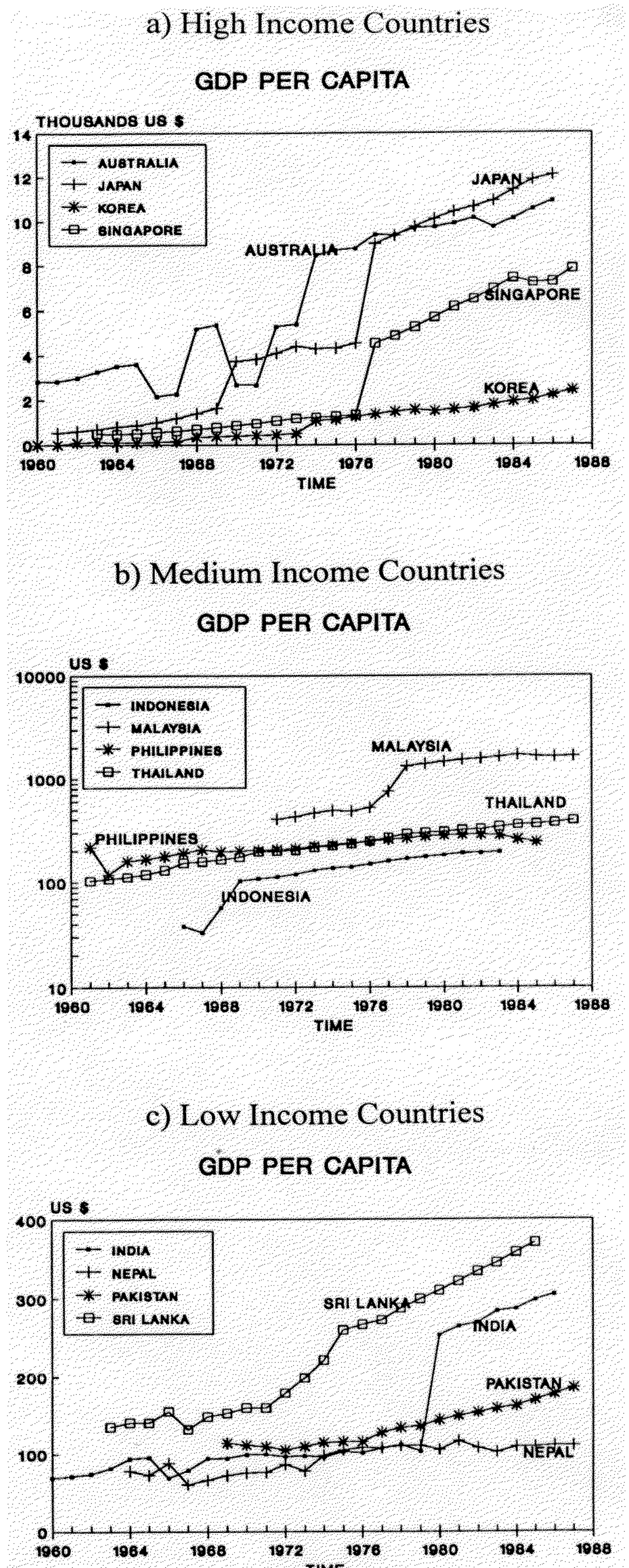


Figure 2 GDP per capita growth

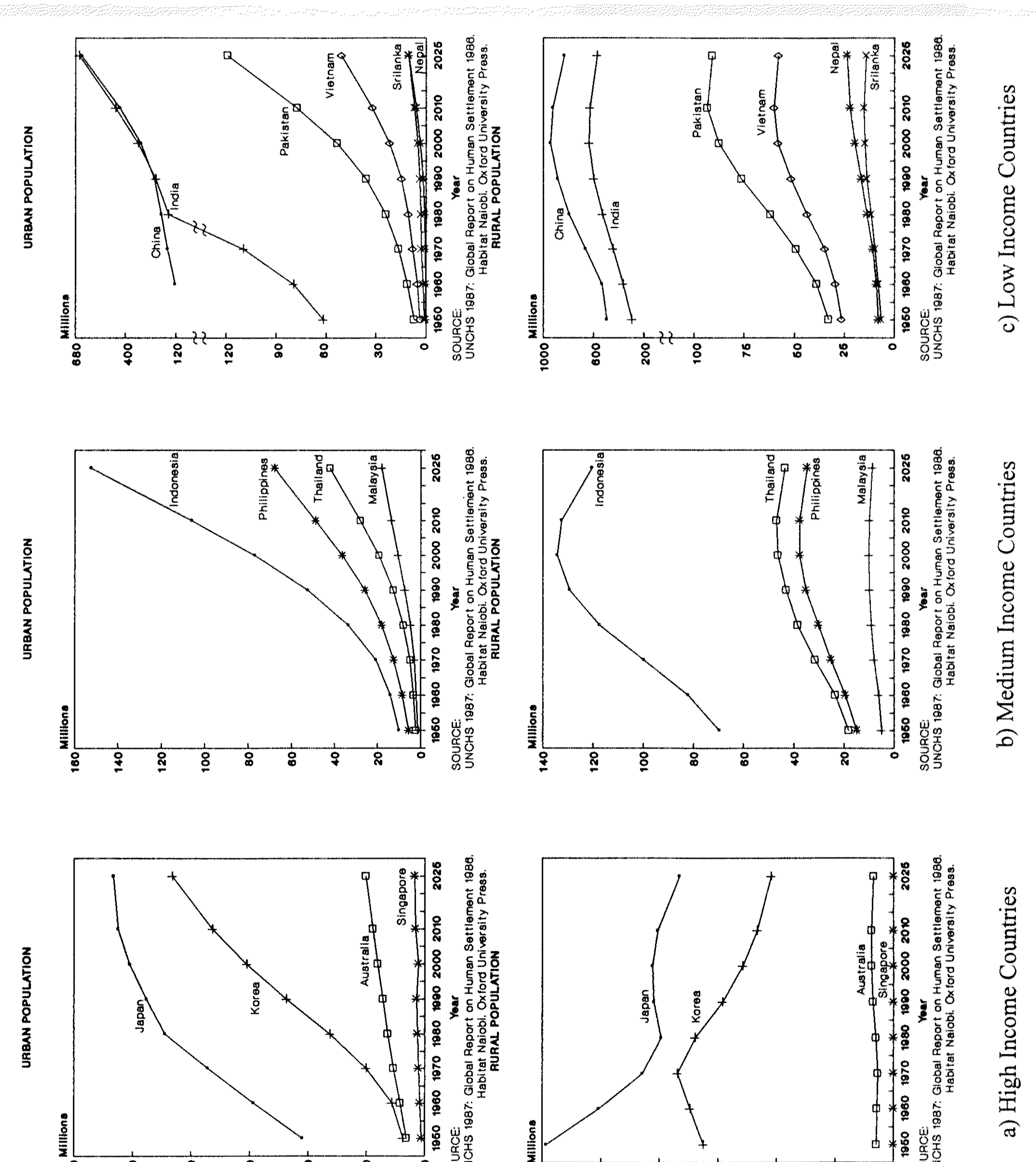


Figure 3 **Projections for urban and rural population**

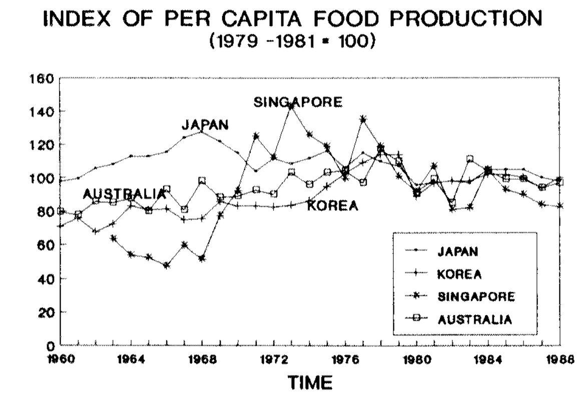
A significant side effect of the expansion of economic base is the growth in urbanization, which is necessitated by the technological choices requiring concentration of production activity to achieve economies of scale. The concentration of human activity, however, may also create concentrated doses of pollution, which the environment is unable to assimilate. The results of this are manifest in a lowering of the water table, pollution of groundwater aquifers and acid rain, all of which adversely effect agriculture. Urbanization also often encroaches on prime agricultural land, which reduces production potential, especially in Asia where only marginal lands remain uncultivated.

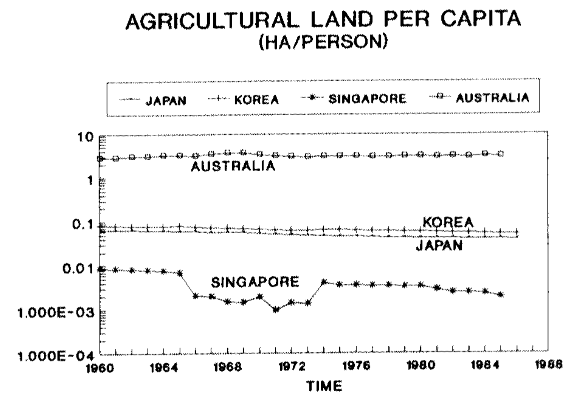
Condition of Renewable Agricultural Resources

Renewable resources considered include agricultural land and forests, which have traditionally met the food, fuel and timber needs of society. Figures 5: 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, contain some inconsistencies in the definitions used to represent the various categories of data. For the purpose of constructing a reference mode defining the agricultural security problem, 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 can 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.

a) High Income Countries





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

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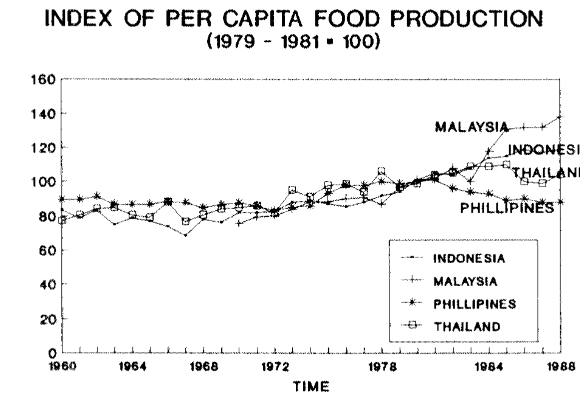
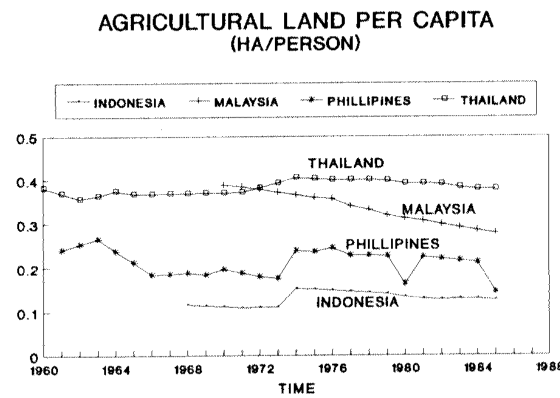
UN 1979: Demographic Yearbook 1978. NY.

b) Medium Income Countries





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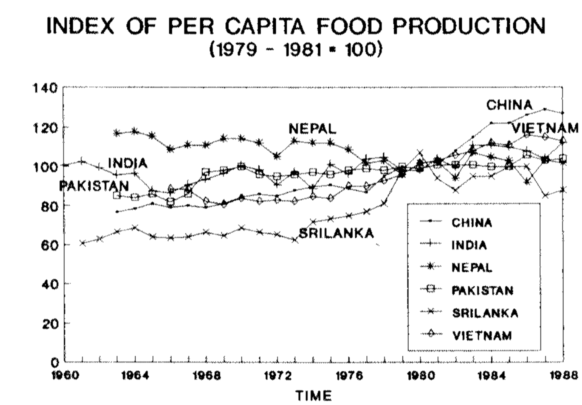
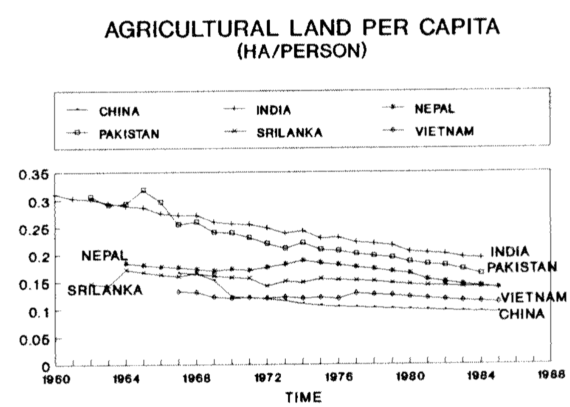
c) Low Income Countries





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

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

Figure 5 Food Production per capita and agricultural land per capita

Indeed, as indicated in Figures 6: 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 7: 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, which do not stand against recognizing the underlying pattern of change. 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 8.

A similar variety of aggregate trends for agricultural production have been reported by the World Resources Institute at the continental level [World Resources Institute Web site 2000].

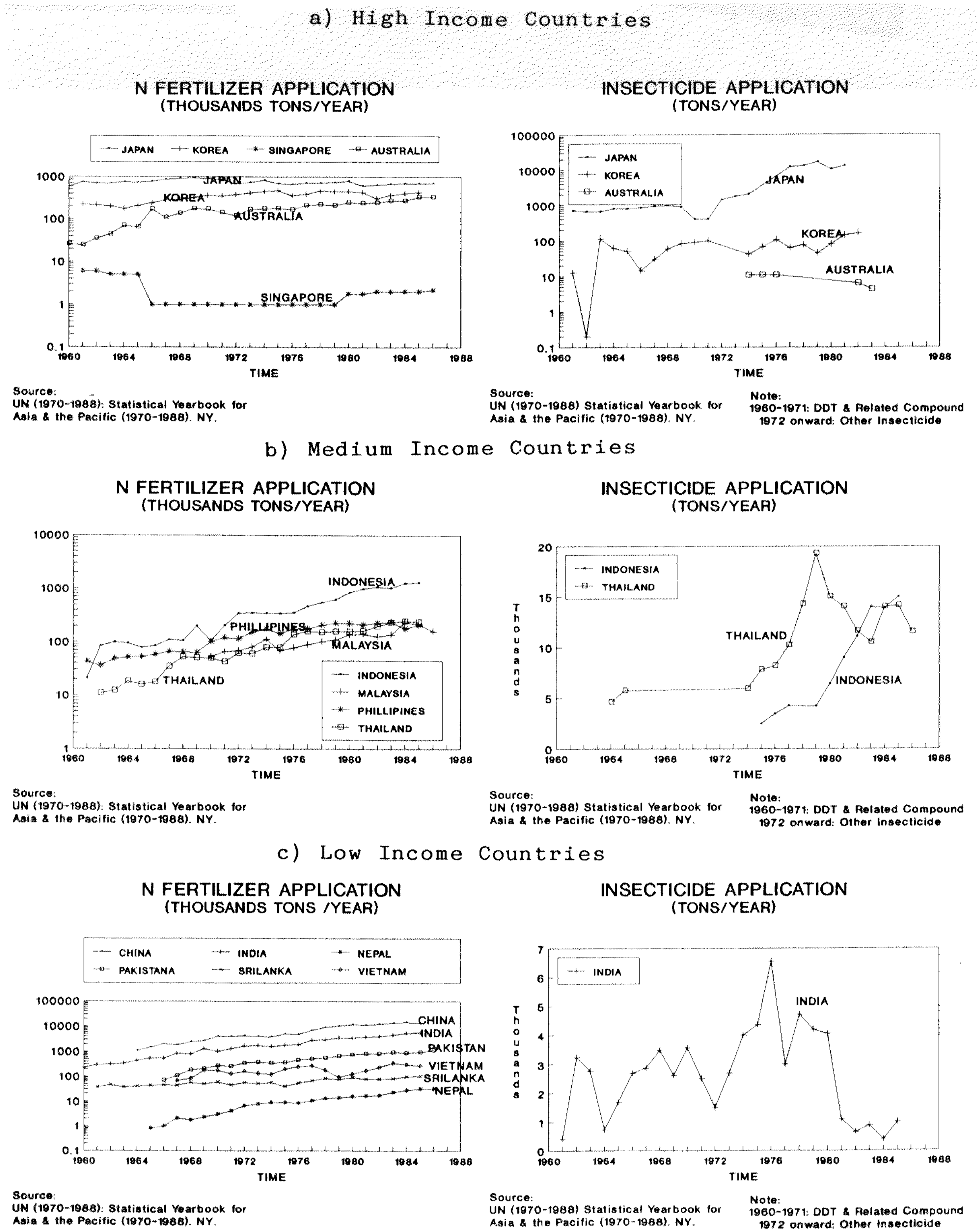
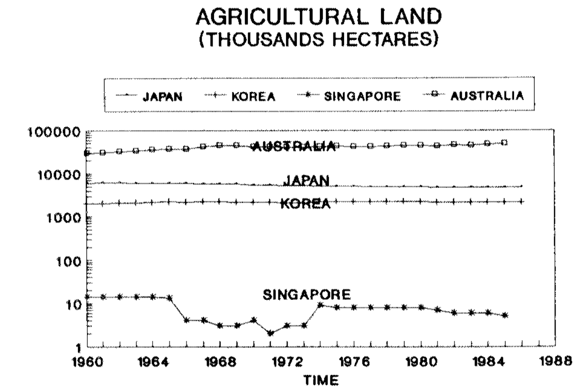


Figure 6 Fertilizer and Pesticide application

a) High Income Countries



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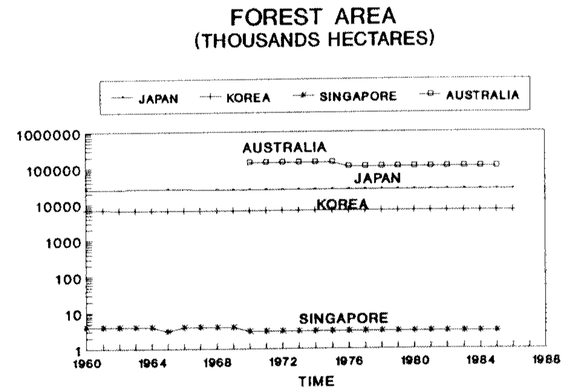

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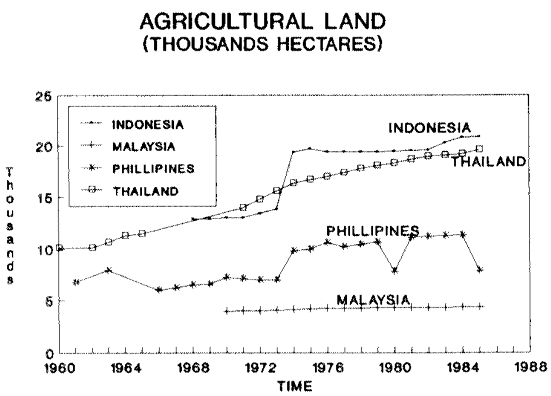
b) Medium Income Countries



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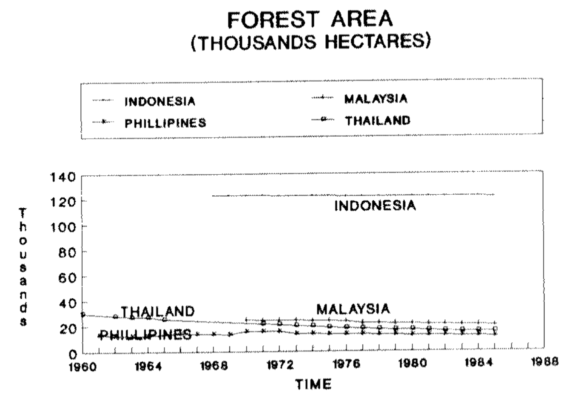

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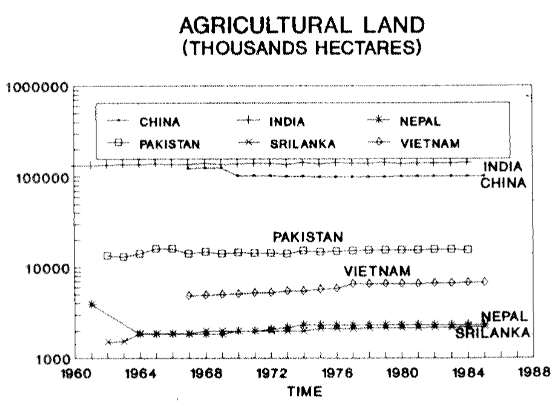
c) Low Income Countries



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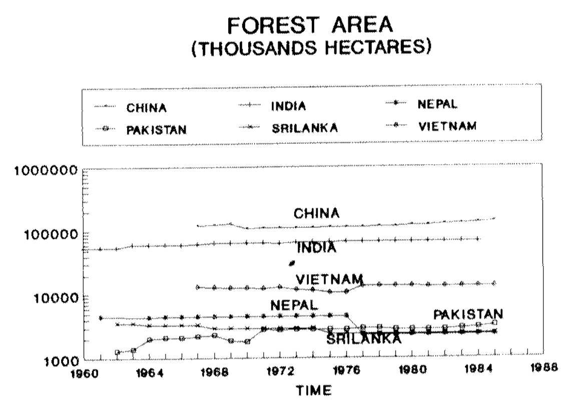

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Figure 7 The competition between cultivable and forest land

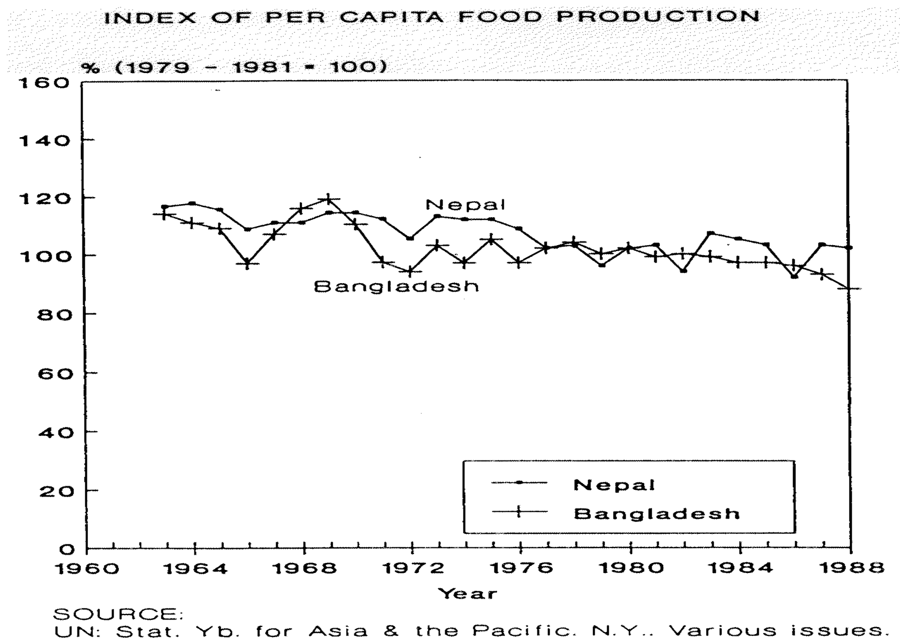

Figure 8 Declining food per capita trends in Nepal and Bangladesh

Agricultural land use pattern inferred from the data

The observed trends in the data taken from a geographically, economically and politically diverse set of countries. They 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 treated 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 has evidently been propped up by fertilizer application, but would eventually decay if the pressure on soil and deforestation continues.

System Relationships in Non-Sustainable Agricultural Development

Excessive use of agricultural land has been known to depreciate soil quality. Soil degradation has occurred in many countries due to erosion, loss of soil- nutrients, loss of texture, water logging and salinity, usually caused by intensive land use [Bowonder 1981]. Centrally planned as well as market-economy countries have encountered these problems. The market economies tend to externalize private costs to the environmental commons since private decisions often view the environment as a free resource. The centrally planned economies, likewise, fail to internalize environmental costs because incentives are provided to managers to boost production, not preserve the environment. Furthermore, since the resources placed in the hands of the managers take account of no scarcity value, no opportunity cost, no real price, the cost of using resources is essentially irrelevant and competition absent [Chandler 1987].

The food production system of the Asian countries can be characterized by the feedback loops shown in Figure 9. Food fulfills nutritional needs of the population; hence, food sufficiency is definitely related to the average life expectancy. An increase in population expands the food consumption base. Consequently, food consumption is stepped up through intensive land use, high yielding seed varieties and extensive irrigation, all of which degrade land in the long run. Yield may also be increased or sustained through investment in land improvement, which is often resorted to after much damage has already been caused. These relationships were incorporated into a formal system dynamics model that was experimented with to understand their implications for future [Richardson 1997]. The model subsumes three subsystems: population, food production and the ecology. The structure of each subsystem is discussed in Bach & Saeed (1992). Mathematical relationships incorporated into the model are summarized in Appendix. Further technical details of the model and a machine- readable listing of its equations is available from the author on request.

The model was parameterized for the ten countries in medium- and low- income categories of the sample, the low-income countries also subsuming the SARC region. The countries of the high-income category seemed to exercise technological options that were not purely pressure-based. It was, therefore, not considered appropriate to attempt to apply the model to those countries. Figure 10 summarizes the results of the simulations of the model with ten parameter sets representing the ambient conditions in the countries of the sample in the middle- and low-income categories.

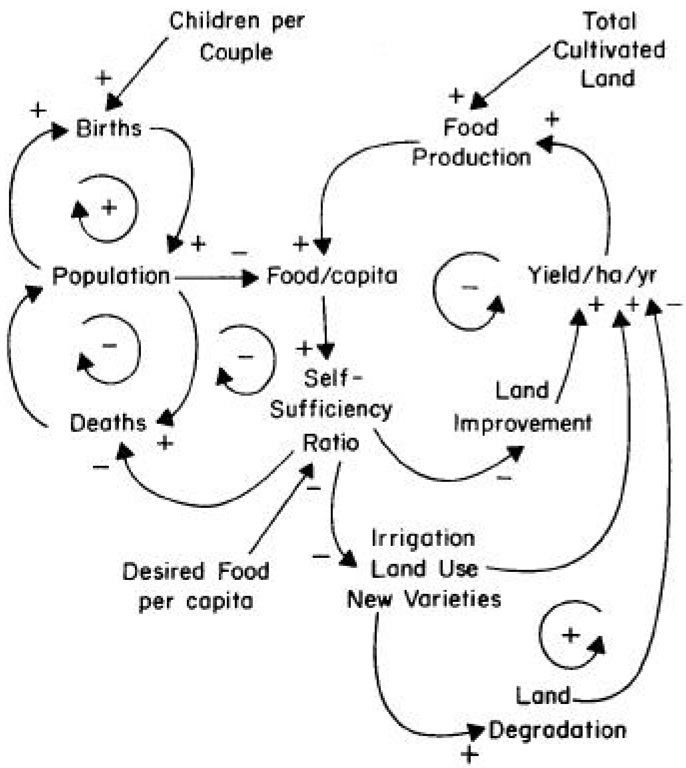

Figure 9 **Key Feedback processes in the food production system**

It is observed that food production per capita can be sustained in most cases until the turn of the century, possibly from increasing application of capital inputs and intensity of cultivation. However, land quality may be expected to deteriorate continuously, which may cause sudden declines in output in the early part of the 21st century unless concerted land conservation and reclamation efforts not included in the model have been put in place. Countries affected most are those with relatively higher population growth rates and more intensive land use.

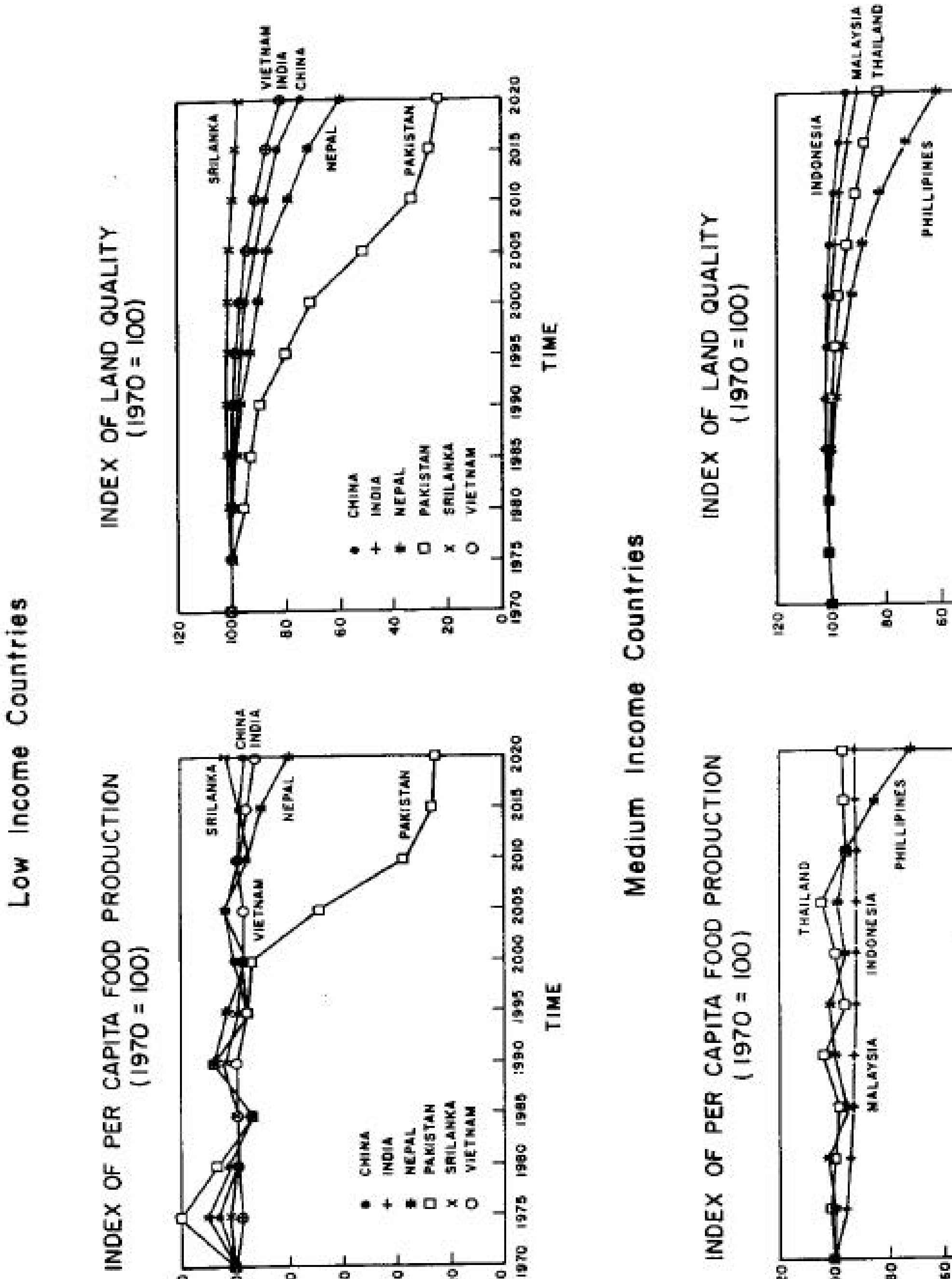

Figure 10 **Model behavior for parameter sets representing countries in low and medium income categories**

Similar trends obtained with the ten parameter-sets representing the low and medium countries of the sample also show that the system is parameter insensitive. Hence, these inferences can be extended beyond the analyzed set.

Since the magnitude of deterioration in the land quality index shown in the simulation does not take existing land management programs into account, it indicates only the volume of effort needed to overcome the deteriorating trends. Yet, the results of the simulations are borne out by the experience of many developing countries with large agricultural economies where fertile agricultural lands have already been extensively damaged due to water logging, salinity, and erosion of top-soil. Of course, some of these countries have already instituted extensive land management programs [Allauddin & Tisdell 1988].

The trends observed in historical data provide persuasive evidence that, over the course of agricultural development, increases in output have been obtained by consuming the resource environment, which has actually reduced food security. The projections made with the help of a model incorporating organic cause and effect relationships show that this process has gone far enough, so that it cannot be sustained for long into the future.

Generating Sustainable Agricultural Policies and Practices

A decision process cannot be divorced from its organizational context and it would be impossible to go beyond pontification on issues concerning a commons unless an institutional framework accepting responsibility for the commons is created. Sustainable agricultural technologies in the form of energy efficient crops and soil preserving cultivation methods are now widely available. There, however, exist neither an adequate awareness of the environmental issues, nor an institutional framework to take responsibility for the environment. Hence, sustainable technologies have a poor chance to become adopted. Following social and institutional policy directions must be pursued to create responsible attitudes towards environment leading to the adoption of sustainable technologies.

Social Policy Directions

Agricultural land ownership is concentrated in few hands in most countries. Hence, cultivators do not have a stake in the preservation of the land they till often on rental or share cropping basis. Even when cultivators do own the land they till, it is often in small tracts that must support large self-employed families with a much higher priority on consumption than on preservation. Finally, there might exist an awareness of the environmental issues and a commitment to preservation, but there are no institutional mechanisms for mobilizing individual initiatives into the maintenance and preservation activities that call for collective effort. Thus, following social reforms must precede any sustainable agricultural development initiative:

1. Fiscal instruments and direct intervention must be introduced for transferring absentee-held (both state and private) agricultural resources to the cultivators so they have a stake in the preservation of these resources.

2. Extension services should be provided to help cultivators increase their income so conservation can take priority over consumption.

3. Community organizations serving the collective interest of small cultivators must be supported to address commons agenda.

4. Infrastructure development must be undertaken for increasing social mobility in the rural areas making it possible for the surplus labor to move into other production sectors so pressure on land is reduced.

5. Fiscal policies should be designed and implemented for creating a crop mix that emphasizes food self-sufficiency on long term basis not income generation from export of primary products.

6. Population control should be stepped up for containing food demand and urbanization.

Institutional policy directions

Current approaches to national planning and policy design often entail fragmented efforts undertaken in the compartmentalized wings of government, which are ultimately assembled into a statement of targets by the central planning organization. This process can rarely identify organizational mechanisms for creating a change, a shortcoming that the plans often ignore. Sometimes, impromptu agendas originating at the top also determine the directions of the plan. To create environmentally sound development policies, it would be necessary to reorient planning activity so it is possible to design organizational instruments of change along with the preparation of statements of targets. This calls for rethinking on the structure of the planning institutions as well as education in socio-economic planning on following lines.

1. The information base affecting the policy space in the preparation of plans must be expanded to include geological and environmental information and models of organic relationships, which may be experimented with to generate environmentally rational scenarios.

2. An information system must be created to assure that the expanded information base does not reside in idle compartments but is actively accessed for making private and public decisions.

3. Since environmental issues may clash with powerful corporate and political interests, environmentally conscious institutions must be created in the form of private, non-government and government interest groups. Such groups must also be given legislative protection and a role in decision making on public agenda.

4. Agricultural research must seek development of seed varieties, and cropping patterns for low energy input rather than for high output.

Conclusion

This paper has attempted to illustrate how the pervasive indifference towards the conservation of the environment on the part of the public and government institutions is creating dangerous long-term trends depleting agricultural resources in Asia. Such attitudes arise from vantage points, both in private and public decisions, that emphasize increasing production in the short run by externalizing costs on the environment whose maintenance is not a responsibility of any of its beneficiaries. The increased availability of production, however, also causes growth in the consumption base, which limits availability, requiring further rises in production. The environmental abuse so inflicted has, by now, created serious deteriorating trends, which threaten sustained agriculture in the region. The policy space for the private and public decisions concerning agriculture must clearly be expanded to incorporate the information about stocks and organic relationships in the interaction between human decisions and the environment, if the deteriorating trends are to be reversed. This is not a simple task and would require major organizational reform, both in planning and use of information and in changing existing attitudes.

It is also suggested that the problem recognition and experimental learning process adopted in this paper is extended to developmental policy design in general. 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 [Saeed 1994a, 1998].

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.

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Appendix

Description of mathematical structure of the model

(1) $d/dt\,(N) = f_1\,(LUI, B) + NFAR - f_2\,(B) - f_3\,(H/IH, N)$;

$LUI = f_4(IP)$; $f'_4 > 0$; $d(f_1) / d(LUI) < 0$; $d(f_1) / d(B) > 0$; $f'_2 > 0$;
$d(f_3) / d(H) < 0$; $d(f_3) / d(N) < 0$

Where, N = soil nitrogen in soil, LUI = land use intensity, B = biomass,
NFAR = N fert. application rate, H = humus, IH = initial H.

(2) $d/dt\,(H) = f_5\,(LUI, B) - f_6\,(LUI, H)$;
$d(f_5) / d(LUI) < 0$; $d(f_6) / d(LUI) > 0$

(3) $d/dt\,(IP) = f_7\,(FR)$;
$FR = PCFP/DPCFP$;
$f'_7 < 0$

where IP = irrigation percentage, FR = ratio, PCFP = per capita food production,
DPCFP = desired PCFP

(4) $d/dt\,(PF) = f_8\,(FR)$;
$f'_8 < 0$;

where PF = product percentage.

(5) $d/dt\,(P) = f_9\,(MCF, P, KPC) - P / (NLE * f_{10}\,(FR))$;
$df_9 / d(P) > 0$; $f'_{10} > 0$;

where P = population, MCF = married couple fraction, KPC = kids per couple, NLE = normal life expectancy.

(6) $d/dt\,(GL) = f_{11}\,(FR) * AL - f_{12}\,(IP) * GL$;
$f'_{12} > 0$;

where GL = good land, AL = adverse land
.
(7) $PCFPI = FR * 100/IFR$;
(8) $LQI = ((N/IN) * (H/IH) * (GL/IGL))^{1/3} * 100$

where PCFPI = PCF index (initial year = 100), IFR = initial FR; LQI = land quality index (initial year = 100); IN, IH, and IGL = initial N, H, and GL respectively.