Working Paper

A Conceptual Framework for Population and Environment Research

Vinod Mishra

WP-95-20
February 1995

IIASA

International Institute for Applied Systems Analysis □ A-2361 Laxenburg Austria

Telephone: +43 2236 807 □ e-mail: info@iiasa.ac.at □ Telefax: +43 2236 71313

A Conceptual Framework for Population and Environment Research

Vinod Mishra

WP-95-20
February 1995

IIASA

International Institute for Applied Systems Analysis ☐ A-2361 Laxenburg Austria

Telephone: +43 2236 807 ☐ e-mail: info@iiasa.ac.at ☐ Telefax: +43 2236 71313

ABOUT THE AUTHOR

Vinod Mishra is a graduate student at the Department of Sociology and the School of Public Health, University of Hawaii at Manoa, Honolulu. He participated in the 1994 IIASA Young Scientists Summer Program (YSSP), working with the Population Project.

All correspondence regarding this paper should be addressed to the author at: Program on Population, East-West Center, Box 1255, 1777 East-West Road, Honolulu, Hawaii 96848, U.S.A.

ACKNOWLEDGMENTS

I want to thank Robert Retherford, Wolfgang Lutz, Warren Sanderson, Arnulf Grübler, Kirk Smith, Anne Babette Wils, Peter Xenos, Barbara Siegel, and Hassan Musa Yousif for their valuable comments on earlier drafts of this paper. I also want to thank the Program on Population, East-West Center; the Department of Sociology, University of Hawaii; and the International Institute for Applied Systems Analysis for their financial support which facilitated the completion of this work. This work also forms an important component of my Ph.D. dissertation.

ABSTRACT

This paper is an attempt to set some basic parameters and outline the scope for population and environment research. After briefly reviewing the present state of theory, the paper outlines an integrated theory of population, development, and environment. The proposed theory presents population and environment in a "transition paradigm." This theory builds on the demographic transition theory and integrates various existing theoretical ideas into a dynamic framework. Demographic transition theory has been modified by incorporating environmental dimensions and rethinking the relationships between demographic processes and development as they interact with environmental changes. The empirical evidence gathered from various sources provides support for the relationships hypothesized in the theory. The proposed theory is a generalized explanation of population-development-environment relationships and encompasses a wide variety of circumstances. For an in-depth understanding of population-environment interactions in an area, detailed case studies must be carried out at appropriate levels of aggregation incorporating the contextual idiosyncrasies.

TABLE OF CONTENTS

1.	Introduction	1
2.	The Present State of Theory	2
3.	The Framework	7
4.	A Theory of Population and Environment Outlined	9
5.	Empirical Evidence	16
6.	Concluding Remarks	27
References		28

A CONCEPTUAL FRAMEWORK FOR POPULATION AND ENVIRONMENT RESEARCH

Vinod Mishra
University of Hawaii

1. INTRODUCTION

Population and environment are closely entwined in a complex and dynamic relationship. The relationship between population and environment is mediated by a number of socioeconomic, cultural, political, and developmental variables whose relative significance varies considerably from one context to another. Over the past three to four decades, some economists, biologists, and environmentalists have been debating the role of population in environmental degradation.[1] The developing countries have been blaming the developed countries for pushing them to reduce their birth rates so that the rich countries can continue with their wasteful lifestyles. Such debates and the blame-game have recently heated up with rapidly increasing visibility of and awareness about environmental problems at both the local and global level (Shaw 1992; Bongaarts 1993).

On the one hand, rapid growth of human population is often identified as one of the main factors behind environmental degradation. Given a socioeconomic and political structure and a given level of technological development, a rapid growth in population can cause environmental degradation. However, the effects of population on environment are seldom clear and straightforward. These effects are often confounded by political economy, consumption patterns, and technological factors. On the other hand, there is ample evidence that environmental degradation can affect the size and distribution of population. Environmental degradation can affect each of the three demographic processes--fertility, mortality, and migration. Environmental degradation can adversely affect human health, which can in turn increase mortality rates and shorten life spans in a population. Environmental degradation can lead to migration, for example, by pushing people off the agricultural lands to other areas as a result of land degradation (Jacobson 1988). Environmental degradation can also affect fertility by increasing the demand for child labor (Feldman 1990; Dasgupta 1992) or by increasing the abstinence periods due to environmentally-induced, sex-selective labor migration. For the most part, the effects of environment on population are also mediated by institutional factors. These factors make the link between population and environment complex. Adding to this complexity is the bi-directional nature of the relationship and a lack of understanding of the relevant variables, their behavior, and the internal dynamics of environmental change (Lutz 1994a). Moreover, there are considerable uncertainties about the likely course of future demographic and environmental changes. Considerations such as long term versus short term, local versus global, and direct versus indirect effects of population on environment and vice versa make the relationship even more unclear.

Realizing the complex and dynamic nature of the relationship between population and environment and the contextual idiosyncrasies, some researchers argue that it is not possible to have a single theory which can adequately explain the interactions between population and environment (for example,

[1] Environmental change is a more appropriate term than environmental degradation, but since this paper is specifically concerned about environmental degradation, the term degradation has been used instead of change. Positive changes in the environment are indirectly addressed as improvements in environmental degradation.

Bilsborrow and Ogendo 1992). Others argue that an attempt to develop such a theory is bound to be so general as to loose any usefulness in a real context (for example, Turner and Meyer 1991). Nevertheless, the need for a comprehensive theory incorporating major dimensions of population, development, and environment with global applicability has been repeatedly proposed (WCED 1987; Davis 1991; Keyfitz 1991, 1992).

This paper attempts to briefly review the present state of theory and develop a broad theoretical framework for the study of population and environment interlinkages. Following this introduction, Section 2 provides a succinct review of the most relevant literature and summarizes various theories on population-development-environment interactions. Section 3 develops a conceptual framework in the form of a box-and-arrow diagram for population and environment research. In Section 4 an outline of a broad theoretical framework is presented. Some country level data and other empirical evidence from various publications are presented in Section 5 to support the propositions in the theory. In Section 6 the paper outlines the scope for future research in this area.

2. THE PRESENT STATE OF THEORY

Population and resource relationship is the most basic underlying subject to all the social sciences. In recent years, the literature on population, resources, and environment has grown rapidly. The majority of the literature on population and environment can be categorized into three groups. The first group presents a pessimistic future environmental scenario under rapidly expanding Third World population, a worsening poverty situation, and the pressing needs for improving the quality of life for large masses in the developing world (Ehrlich and Ehrlich 1970, 1990, 1991; Meadows *et al.* 1972, 1992; Hardin 1968, 1993). In direct contrast with the environmentalists' view are the views of a few "technological optimists," mostly neoclassical economists. This group presents a world view that does not acknowledge any limits to growth. From this perspective, market mechanisms and technological developments are seen as answers to all resource problems, and population growth is seen as an asset, not a hindrance, to development (Simon 1977, 1980, 1981, 1986; Simon and Kahn 1984; Smil 1990; Kates and Haarman 1992).

There are, however, many researchers who fall between these two extremes (Blakie and Brookfield 1987; Myers 1992; Shaw 1992; Commoner 1991; Bongaarts 1993). These researchers recognize the significance of population growth in environmental degradation but do not see population as the main or direct cause of it. This middle perspective can be divided into several categories depending on what it emphasizes in the study of population and environment. Working within the "world systems" perspective, some researchers argue that in developing countries both demographic and environmental conditions are shaped by international economic and political forces. Slightly different from this perspective is what is sometimes labeled as the "neo-Marxist political economy" perspective. According to this perspective, profit seeking and capital accumulation require the unsustainable exploitation of natural resources, and socioeconomic differentiation in a society creates a situation in which the "haves" place heavy demands on the world's resources, primarily driving environmental changes while the subsistence needs of the "have nots" put marginal environments under pressure (Blakie and Brookfield 1987; Myers 1992). This viewpoint emphasizes the role of the means of production in the global economy of international capitalism.

Some researchers argue that the obstacles to the proper allocation of costs are the main cause of environmental degradation. These obstacles may originate from an imperfect information regarding resources or due to an artificial distortion of prices through subsidies for many environmentally destructive services and technologies (World Bank 1992). This viewpoint is sometimes categorized as the "neoclassical political economy" perspective. There is another middle perspective which argues that improper use of technology is the main cause of environmental degradation. According to this perspective rapid increases in population can worsen the problems created by the improper use of technology.

Although the growing concern about the role of population growth in environmental degradation is a relatively recent phenomenon, the study of the population-resources (especially food) relationship is not new. Malthus and Boserup are the two most important names in the literature on population and environment. As early as the late 18th century, Thomas Malthus laid the foundation for a theory of population-resource interrelationships by proposing that a geometrically growing population tends to outrun an arithmetically growing food supply. According to Malthus, over the long run population and resources remain in a state of equilibrium mediated by the available technology of food production and the prevailing living standard (Malthus 1960; Lee 1986; Winch 1987). Malthus assumed that the natural resources are fixed and he is often criticized for not including a possibility of technological change. Ricardo and Mill, in general, supported Malthus' thesis that population growth beyond a certain density is harmful to human welfare and the economic development (Keyfitz 1991). Other classical social theorists of the 18th and 19th century such as Marx, Weber, and Durkheim, also paid some attention to natural resources and the environment.

Malthus' views were the basis for discussion of population and resources for more than 150 years until challenged by Ester Boserup in 1965. Boserup (1965) criticized the Malthusian theory on the grounds that it exclusively focuses on food-production technology and ignores the effects of technological changes in other sectors and the effects of environmental changes. She also criticized Malthus for not considering the effects of population change on both technology and environment (Boserup 1976). Refuting the Malthusian assumption about unchanging technology, Ester Boserup postulated that increasing population pressure itself induces technological change, leading to a more intensive use of land (Boserup 1965, 1981). This became popularly known as "Boserup's land-intensification hypothesis." Boserup argued that under given agroclimatic conditions, the agricultural system slowly shifts from forest fallow to annual multiple cropping due to increasing population pressure.

Recently, Bilsborrow (1987) and Bilsborrow and Ogendo (1992) presented a theoretical framework for studying the effects of population change on agricultural development in rural areas of developing countries. Bilsborrow builds upon Ester Boserup's land-intensification hypothesis and Kingsley Davis' theory of demographic change and response[2] (Davis 1963), and he suggests a set of several possible demographic and non-demographic responses to increases in population density, such as land intensification through irrigation, fertilizer, and pesticide use, land extensification, higher age at marriage, contraception, abortions, increased abstinence, and net out-migration. He has argued that a particular response or a combination of responses depends upon the stage of agricultural development in that region. Several factors, such as the existing level of living, availability of potentially cultivable land, availability of off-farm employment opportunities, size and distribution of land holdings, potential for labor and technological intensification, rural fertility level, rural-urban population distribution, and existing crop structure, determine the type of response(s) to be expected. He emphasizes the role of socioeconomic and institutional factors in determining the nature of such responses. Bilsborrow has criticized Kingsley Davis for not including non-demographic responses to increases in population pressure and not specifying the nature, importance, and relationships between different possible responses in his change-response formulation. He has also criticized Boserup for not including "land extensification," mainly through rural-to-rural out-migration, as a response to increases in population density.

[2] The theory of demographic change and response builds on the demographic transition theory by specifying sociodemographic responses to mortality decline and population growth during the transition phase.

Bilsborrow's criticism of Boserup for not including "land extensification" in her theory is somewhat problematic. In fact, according to Boserup (1965 and 1981), the opportunities for land extensification are exhausted first; then further increases in population density lead to land intensification by substituting traditional farming practices with mechanization or bio-chemical intervention or both. Other authors, notably Kumar (1973), Bryant (1978), and Shapiro (1993), have also recognized that Boserup's formation fully included opportunities for land extensification. However, the manner in which Boserup included land extensification in her theory is problematic because in most populations, land intensification does not necessarily wait for an exhaustion of land-extensification opportunities. Land intensification starts well before all potentially cultivable land is put to use. This phenomenon is quite evident in many Latin American and Asian countries. For example in the case of India, several irrigation schemes started in the second half of the 19th century, while considerable land extensification continued until after the middle of the 20th century (Richards 1986).

This argument is further supported by Binswanger and Pingali, who argue that medium and large-scale government-induced infrastructural investments become essential long before all potentially cultivable land is brought into agriculture (Binswanger and Pingali 1985; Pingali and Binswanger 1987). Pingali and Binswanger believe that infrastructural investments can play an important role in speeding up the process of land intensification. They distinguish between farmer-based innovations, and science and technology-based innovations. The farmer-based innovations include changes in land use, land investments, development of organic fertilizer use, and the evolution of the tool systems. Science and technology-based innovations include development of agricultural industry, science-based induced technological change, and development of agricultural research institutions. The authors argue that the farmer-based innovations can only support slow growing populations. For rapid population growth they need to be supplemented with science and technology-based innovations.

Kumar (1973) in a detailed analysis of country-level data, finds support for Boserup's intensification hypothesis. Kumar observes that high agricultural density, resulting from increasing population, leads to more intense cultivation of land rather than land abandonment and migration to urban areas. Although Kumar does not explicitly refer to the "change and response theory," its implicit application is apparent in his work. Kumar also finds responses to rural population pressure similar to those mentioned in Bilsborrow (1987) and Bilsborrow and Ogendo (1992). One important difference between Kumar's findings and Bilsborrow's formulation is that, for Kumar, migration to nonagricultural areas is more due to "pull" factors than to "push" factors.

Around the same time, Bryant (1978) also finds support for Boserup's hypothesis and formulates both demographic and non-demographic responses to increasing rural population density. His findings were similar to those discussed in Kumar's work and those later conceptualized by Bilsborrow (1987), and Bilsborrow and Ogendo (1992).

In a historical study of population growth, agricultural productivity, and land degradation in Machakos district in Kenya, Tiffen and Mortimore (1992) and English (1992) also find support for Boserup's hypothesis. They observe that colonial policies before the Second World War, when population growth was relatively slower, were mainly responsible for low agricultural productivity and widespread land degradation in the district. But after the Second World War, when the population of the district grew much more rapidly, it was accompanied with improved food production and considerable improvements in land degradation.

In a review of population pressure effects on environment and land intensification in six sub-Saharan African countries, Lele and Stone (1989) question the appropriateness of Boserup's hypothesis by showing that higher population densities do not necessarily result in higher yields, better inputs, and larger incomes, especially for small farmers in resource-poor areas. They point at a number of inherent limitations in Boserup's formulation, such as: Boserup did not hypothesize rapidly-rising densities and highly-skewed distribution to land in the developing countries; she did not conceptualize substantial concentration of population even in the land-abundant countries; she did not visualize the land-mining tendency among poor farmers; and she overlooked the fact that for poor households there is often a built-in conflict between social and private gains in having a large family. Lele and Stone suggest that in such situations a "policy-led intensification" is needed to supplement the demand-driven (autonomous) intensification suggested by Boserup.

In a more recent descriptive study of 38 sub-Saharan African countries, Cleaver and Schreiber (1992) conclude that in sub-Saharan Africa a "population, agriculture, and environment nexus" exists in which the effects of rapid population growth, stagnation in agriculture, and environmental degradation are mutually reinforcing. The findings from Cleaver and Schreiber's study are similar to those from Lele and Stone's work.

Dasgupta (1992) also argues that in situations of extreme poverty and highly-degraded environment, Boserup's theory does not work. According to Dasgupta, in such societies people are often caught in a "vicious cycle" of poverty-population growth-environmental degradation-poverty. The *1992 World Development Report* (World Bank 1992) and the *World Resources 1994-95* (WRI 1994) also refer to such vicious cycles often observed in the poor areas of developing countries.

Drake (1994) presents a set of important ideas for understanding population-environment dynamics. According to Drake, the complex dynamics of population and the environment should be visualized as a family of transitions. He describes nine different sets of transitions: demographic, epidemiologic, forestry, energy, education, urbanization, agriculture, technology, and toxicity, and suggests that efforts should be made to study their interconnectedness in order to understand the dynamics of population and the environment. He, however, does not identify the possible relationships between various members in his family of transitions and fails to integrate these transitions into a theoretical framework.

Hayami and Ruttan (1987) present yet another useful theoretical idea, popularly known as the "induced-innovation hypothesis." According to this hypothesis, in agriculture the constraints imposed on development by an inelastic supply of labor may be offset by advances in mechanical technologies, while the constraints imposed by an inelastic supply of land may be offset by biological technology. The examples of the first situation are typical of developed countries, while examples of the second type are found in developing countries in general. The Hayami-Ruttan hypothesis helps to explain why large-scale mechanization of agriculture is not very appropriate in developing countries that have an unlimited supply of labor and limited land.

A small group within sociology emphasizes the need and importance of including ecological variables in sociological analyses. This minority group is often labeled as the "human ecology" perspective. There is considerable variation within human ecology in the manner in which different proponents of human ecology have visualized the relationships between population and environment. The major building blocks in all these formulations are population, organization, environment, and technology, to use Duncan's terminology. By combining these four basic components (P,O,E,T), Duncan (1959, 1961) created his famous "ecological complex" where the relationship between human population (P) and its environment (E) is mediated by socioeconomic organization (O) and technology (T). However, population is also seen as directly interacting with the environment. Before Duncan proposed his ecological complex, there were two other major perspectives within human ecology, one that followed Ogburn (1922) and the other after Park (1936). Ogburn, conceptualizing the link between population and environment differently from Duncan, argued that humans must adapt not only to their natural environment as other animals but also to a social and a technological environment; society and technology are also viewed as environment and humans are expected to adapt to all three environments. Park differed considerably from Ogburn in his formulation in that he argued that technology and social organization should be regarded as an extension of humans. He defined a "social complex" consisting of population, its artifacts, and its non-material culture inside an environment interacting with it.

The contemporary sociological human ecology is based mainly on Amos Hawley's work and places major emphasis on the social organization. According to this perspective, changes in environment and technology affect the organizational structure which in turn brings about changes in population (Hawley 1986; Frisbie and Poston 1975). From this perspective the relationship between population and environment must be formulated in organizational terms as organizational context is central to both population and environment changes. Frustrated with main stream sociology's neglect of biological and physical environment in general, and contemporary sociological human ecology's over-emphasis on social organization, recently Catton and Dunlap proposed a new perspective called "environmental sociology" (Catton and Dunlap 1978; Dunlap and Catton 1979). Their environmental sociology paradigm is based on three basic assumptions which environmental sociologists believe have become essential to understand social change: (a) human beings are but one species among the many that are interdependently involved in the biotic communities that shape our social life; (b) intricate linkages of cause and effect and feedback in the web of nature produce many unintended consequences from human action; (c) the world is finite, so there are potent physical and biological limits constraining economic growth, social progress, and other societal phenomena.

Much like the contemporary human ecology, the work of McNicoll (1990, 1993) emphasizes the role of social organization in mediating the relationship between population and environment. McNicoll, however, deviates from human ecology in that to him changes in population can also bring about changes in the social structure and technology which in turn can change the relationship between population and environment.

The equation I=PAT developed by Ehrlich and Holdren more than two decades ago provides a multiplicative framework for studying the impact of population growth on the environment. In the equation, the impact (I) of a society on the environment is viewed as the product of its population size (P), per capita consumption or affluence (A), and a measure of environmental damage done by the technologies (T) used in providing each unit of consumption (Ehrlich and Holdren 1971; Ehrlich and Ehrlich 1990). In recent years, this equation has been extensively used by a number of researchers to demonstrate the role of population growth in environmental degradation (Holdren 1991; Ehrlich and Ehrlich 1990, 1991; Commoner 1991, 1992; Bongaarts 1992; Clark 1992; Harrison 1991, 1992). This equation has been criticized on several grounds. The main criticisms of the equation are that the results of this equation depend upon the level of aggregation and that the components P, A, and T in the equation are not independent, as implied by the equation (Lutz 1994a; Shaw 1992). In addition, the equation ignores international trade, assumes same causal components for all types of environmental impacts, and does not take into account the sociocultural, political, and other institutional aspects of consumption and technology.

In recent years, several attempts have been made to develop conceptual frameworks linking population, environment, and many related socioeconomic, cultural, and political factors diagrammatically. These efforts vary in their degree of complexity depending upon whether the model is generalizable or not, the direction of hypothesized causal links, and the variables included in the framework. While these efforts, usually in the form of box-and-arrow diagrams, cannot be called theories in any strict sense, they often provide useful structures for empirical research because they list specific variables and directions of causality. The examples of such efforts range from complex frameworks, such as UNFPA (1991), Shaw (1992), Harrison (1992), Lutz (1993 and 1994b), Turner and Meyer (1991) to simplistic ones, such as Kim (1993), Li (1991), May (1993). Some of these important frameworks are briefly reviewed in the following.

The conceptual framework developed by Shaw (1992) subsumes the I=PAT formulation discussed above, and includes political considerations in addition to demographic and economic in determining environmental damage. Shaw distinguishes between "proximate" and "ultimate" causes of environmental degradation. He views population growth as a proximate cause or an aggravating factor in environmental degradation which if controlled can provide the much needed time to deal with more ultimate causes, such as poverty, consumption levels, and polluting technologies. The framework emphasizes the role of mismanagement policies in causing environmental degradation.

Lutz (1994b) developed a conceptual framework for studying population-development-environment interactions in Mauritius. The basic underlying philosophy of this model is that population is viewed as embedded in the socioeconomic sphere which in turn is embedded in the environment. People interact with air, water, land, and energy (the four basic life-support systems) through the man-made physical and organizational infrastructure. Humans also interact with other species which directly interact with life-support systems.

The framework developed by Turner and Meyer (1991) for the "Earth Transformed Program" links the determinants and consequences of land-use/land-cover changes. The human activities that directly alter the physical environment by altering the characteristics and distribution of land surface are identified as proximate sources of change. These are governed by five underlying human driving forces: population growth, technological change, economic development, socioeconomic organization, and attitudes and beliefs. These driving forces are hypothesized to influence proximate sources of change via a host of factors operating at the "regional to local" level.

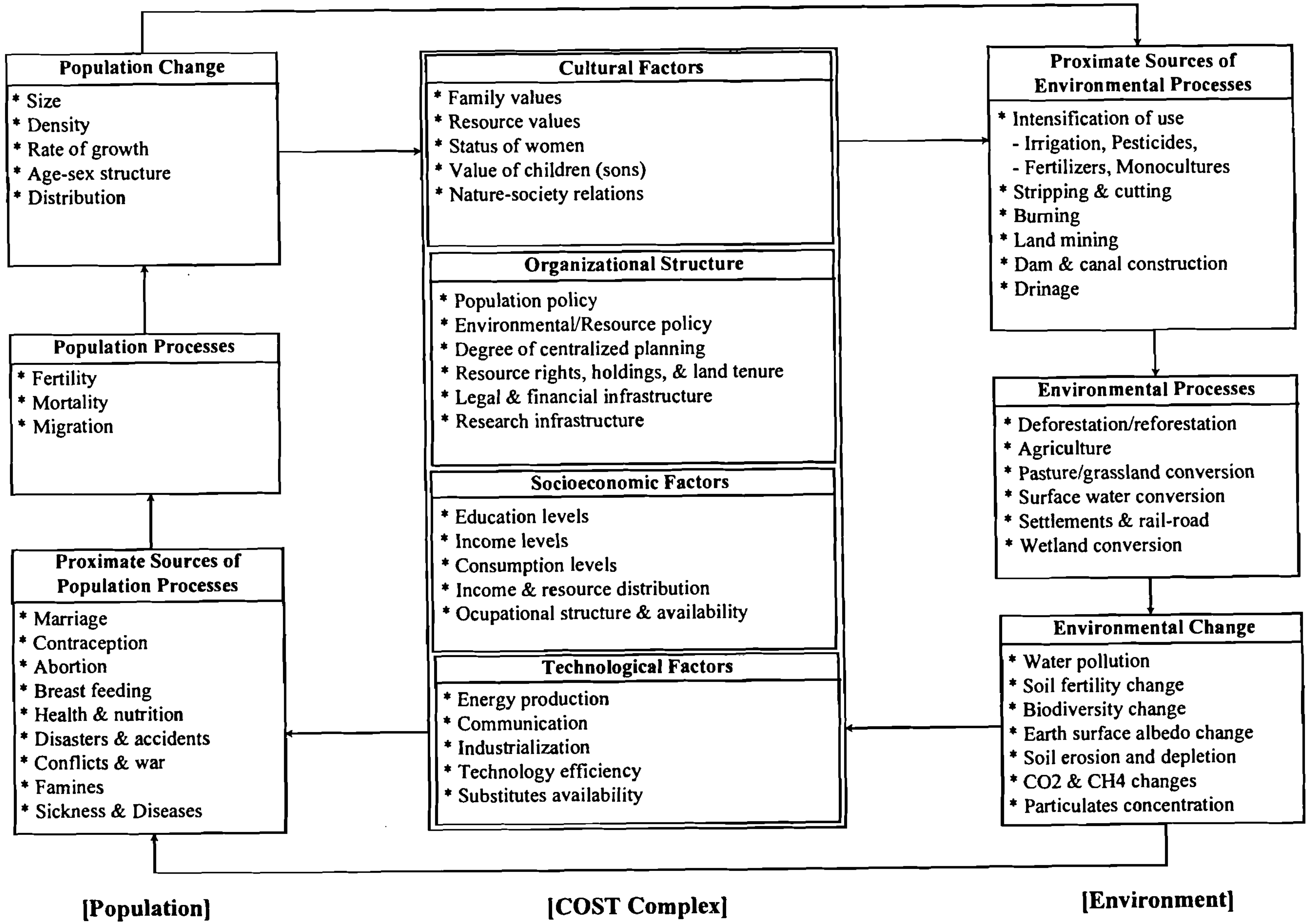
None of the available frameworks for the study of population-environment interrelationships incorporates demographic processes and their proximate determinants. Moreover, none of the existing frameworks includes the possibility of direct links between population and environment variables. The relationship between population and environment is seen as mediated only through institutional variables. The basic conceptual framework to study population, development, and environment interactions outlined in the following section (see Figure 1) remedies some of these deficiencies.

From the preceding review of theoretical and conceptual ideas, it is clear that there is no integrated theoretical framework for understanding population and environment interactions. To fill this gap, a general theory of population and environment is outlined in Section 4.

3. THE FRAMEWORK

To understand the basic structure of relationships between population, development, and environment, a conceptual framework in the form of a box-and-arrow diagram has been presented in Figure 1. This framework draws considerably from Lutz (1994b), UNFPA (1991), Turner and Meyer (1991), Shaw (1992), and May (1993). The framework differentiates changes in population and environment from their underlying processes and proximate determinants and incorporates these processes and proximate determinants in the study of population and environment.

Figure 1. A conceptual framework for the study of population and environment.



On the population side, changes in population characteristics are caused by levels and trends in the three basic demographic processes: fertility, mortality, and migration. At the next higher level, the proximate determinants of these demographic processes are included. The proximate determinants of fertility are better known in the literature than those for mortality and migration. The proximate determinants of migration are by far the most complicated and vary considerably from one context to another.[3]

On the environment side of the framework also, environmental changes are seen as caused by a set of environmental processes, which are in turn governed by their proximate determinants. There are two major sets of processes--industrial metabolism and land-use/land-cover changes--that bring about changes in environmental dimensions (Turner and Meyer 1991). For simplicity, in the conceptual framework presented in Figure 1, only environmental changes relating to changes in land use and land cover and their proximate determinants are included. However, the framework can be generalized by including environmental changes due to changes in the processes relating to industrial metabolism and their proximate determinants. It is also possible to replace land-use/land-cover changes and their proximate determinants with processes and proximate determinants relating to industrial metabolism. The proximate determinants of industrial metabolism are relatively more difficult to identify.

In this framework, changes in population and environmental characteristics are linked with changes in cultural, organizational, socioeconomic, and technological factors. In any society, these factors continually interact with each other and form a dynamic complex. This dynamic complex can be labeled the "COST Complex" if cultural (C), organizational (O), socioeconomic (S), and technological (T) factors are arranged in that order. The selection of the COST acronym is arbitrary and there is no reason for this particular ordering of factors. In the framework, this dynamic COST complex represents "development" broadly defined. In any society, a major part of the relationship between population and environment is expected to be mediated by the factors included in the complex. The COST complex is seen as directly affected by changes in population and environmental characteristics but affects them only through the proximate determinants of population and environmental processes on either side of the diagram. Specific variables under each category of the complex are listed in the framework. However, the list of variables included in the figure is not comprehensive and needs to be changed depending upon the context under investigation. The framework also hypothesizes direct links between population change and the proximate determinants of environmental processes, and between environmental change and the proximate determinants of population processes. The strength of these direct links is expected to depend upon the resource base and the institutional structure of a particular society.

4. A THEORY OF POPULATION AND ENVIRONMENT OUTLINED

A general theory of population and environment can be conceived by modifying the demographic transition theory. Simply stated, the demographic transition theory refers to a shift from high to low mortality and fertility as a consequence of economic and social development. Because mortality decline tends to start before fertility decline, population usually grows rapidly during the transition. Eventually, both mortality and fertility tend to stabilize at low levels, completing the demographic transition (Davis 1954, 1991; Coale 1973). This is more so in the case of mortality. Fertility has not yet stabilized even in most industrialized countries where very low levels of fertility have been achieved over the last few decades. When fertility stabilizes it may amount to irregular fluctuations within certain limits. In

[3] The proximate determinants of mortality are not categorized in the demographic literature as such. However, many factors such as disasters, accidents, wars, famines, and epidemics can be labelled as the proximate determinants of mortality and migration. There is obviously need for more research in this area.

general, before transition the death rate usually fluctuates more than the birth rate, but after transition, the birth rate is likely to fluctuate more than the death rate. The demographic transition theory is based mainly on the experience of Western European and North American countries. In these countries, the transition from high-high to low-low has typically been accompanied by increased standards of living through improved education, urbanization, technological development, and economic growth. The demographic transition theory, in this sense, can be conceived as a part of a general theory of modernization. For the most part, the demographic transition theory, like most other demographic, sociological, and economic theories, takes the natural resources and biophysical environment as given and assumes that they affect demographic processes only through sociocultural and economic conditions. The development is perceived as independent of demographic changes and changes in the resource base and the environment. The demographic transition theory has also been criticized for its poor predictive power.

Despite its criticisms and weaknesses, the demographic transition theory still presents the single most useful broad theoretical framework for understanding changes in population size, growth, structure, and distribution in an area, as these evolve along some developmental path.

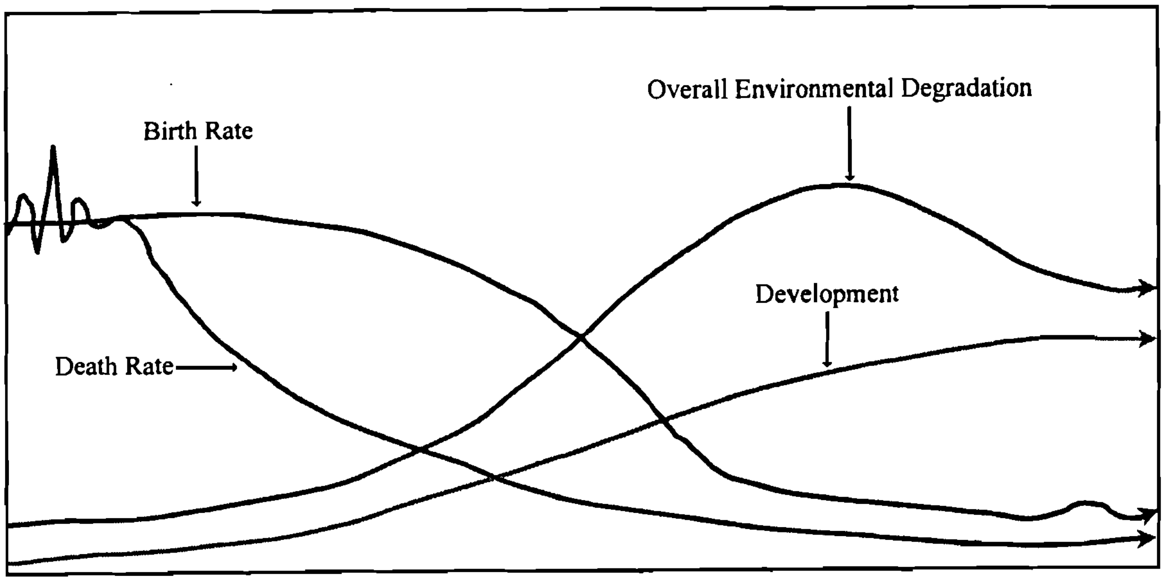
General Statement of the Proposed Theory

The demographic transition theory can be modified by incorporating environmental dimensions and rethinking the relationships between demographic processes and development as they interact with environmental changes. The proposed theory recognizes that population, development, and environment are inseparable and assumes a dynamic relationship between the three in which changes in each can induce changes in the other two. In general, the theory hypothesizes a slow increase in overall environmental degradation with the onset of demographic transition. After some time, with growth of population in conjunction with growth in human consumption and growth in environmentally destructive technology and industry, the rate of overall environmental degradation starts increasing rapidly beyond some critical point. This abrupt change is expected because the stress on the ecosystem generated by the above factors can keep building up for some time, without showing much outward sign of damage to the environment. But when the limits of the ecosystem's tolerance are approached, an abrupt change is likely to occur (Myers 1992). The relatively rapid rate of increase in overall environmental degradation is likely to continue until it reaches its peak, most likely some time after the demographic transition is completed and a certain level of development or standard of living is achieved. Thereafter, it is likely to start declining slowly before stabilizing at some sustainable level. This general formulation of the theory is diagrammatically presented in Figure 2.

Most societies undergo a transition in overall environmental degradation level along with modernization and demographic transition. On the basis of the above description, transition in the overall environmental degradation can be divided into three broad phases: pre-transition, transition, and post-transition. The overall environmental degradation in a society moves from a relatively stable state at some low level in the pre-transition phase to another relatively stable state, most likely at some higher level, in the post-transition phase. The transition phase can be subdivided into two phases: deterioration and improvement. Starting with a relatively low stable state in the pre-transition phase, overall environmental degradation first deteriorates till a certain point and then improves until it stabilizes and completes the environmental transition. Within the deterioration phase, environment first deteriorates rather slowly before reaching a certain critical point, depending on the resource base, population pressure, and institutional structure in a society, beyond which the environment deteriorates more rapidly until it peaks and enters the improvement phase.

The curves presented in Figure 2 are not inevitable. They simply represent a general pattern in population, development, and environment which incorporate many contextual variables and can be influenced by changes in many factors such as those discussed in the COST complex of Figure 1. In this general formulation, the slopes of the curves and timings in a particular context are likely to depend upon the resource base; population pressure; sociocultural, economic, and technological factors; and existing political structures. It is important to recognize that the overall environmental degradation curve includes a wide variety of environmental dimensions. The improvement phase is not inevitable for all environmental dimensions. There is understandably very little automatic about this improvement. It mostly comes as a result of deliberate efforts on the part of people and governments to solve environmental problems. However, their willingness and capability to bring about an improvement in any particular environmental dimension may in part be driven by the population pressure and the level of development.

Figure 2. Stylized patterns in population, development, and environment.



For different dimensions of environmental degradation, such as deforestation, air pollution, greenhouse gas emissions, water pollution, and land degradation, different transition curves may be observed. Different environmental dimensions may be in different stages of transition. It is possible that, while the overall environmental degradation follows the stylized pattern shown in Figure 2, some environmental dimensions may never experience either the degradation phase or the improvement phase. It is also possible that in a society some environmental dimensions are improving, while other dimensions are degrading. Within, say for example, air pollution dimension, indoor air pollution and city air pollution may have different transition curves and even within city air pollution the composition of pollutants, such as suspended particulate matter and sulfur dioxide may be changing. It is possible that in a particular city the sulfur dioxide concentration is increasing, while the concentration of suspended particulate matter is decreasing or vice versa. To further complicate the issue, environmental degradation in any one dimension could be of three types: quality, quantity, and variety. Some combination of these three types of degradation usually operates in any particular environmental dimension.

To combat these problems of diversity and complexity, environmental dimensions have been categorized into three broad groups--local, regional, and global--on the basis of their scale and proximity to people. According to this categorization, environmental dimensions, such as indoor air quality, drinking water quality, and sanitation conditions fall under the local category; urban and rural air quality, surface and ground water quality, land degradation, deforestation, desertification, and species extinction fall under the regional category; and greenhouse gas emissions and depletion of ozone layer fall under the global category. In other words, environmental dimensions in the closest proximity to people are categorized as local; those relating to basic life-support systems air, water, land, and other species, but somewhat detached from the most immediate environment, are grouped as regional; and the ones which are further detached from people and have long-term, indirect, and relatively static effects on people are categorized as global. These categories are not mutually exclusive and there is a considerable amount of overlap. Moreover, it is possible that some dimensions that are regional to one group of people may be local to others, for example, deforestation may be categorized as regional to most city people, while it may be very local to a tribe directly dependent on it.[4]

The theory hypothesizes that degradation in environmental dimensions in closer proximity to people is likely to peak earlier than those dimensions which are more detached and which have relatively longer term and more indirect effects on people's health and well-being. This could in part be due to the fact that the environmental degradation in closer proximity to people often involves most basic needs and services which directly affect human health. Such dimensions are, therefore, given a higher priority both by local governments and international donor agencies. Also, there is often a greater demand from people for the abatement of environmental problems in their closer proximity. The other reason could be that the costs associated with the degradation of a more detached environment are often borne by others and benefits are derived by those who degrade it. In addition to this cost externalization, costs associated with environmental degradation that affects people in a very long run, sometimes as long as several generations, are not perceived as high.

Like environment, the development curve in Figure 2 includes many dimensions in addition to economic growth. As discussed in the "basic framework" section of this paper, development also includes sociocultural, technological, and organizational dimensions. Each of these dimensions of development are composed of several subdimensions. When considered separately, the shapes of various dimensions of development may be different; for example, the shape of the social development curve in a society may be different from the shape of the economic development curve. Also their implications for demographic transition and environmental degradation may be quite different.

Economic development is usually associated with industrial development, increased consumption patterns, and wasteful lifestyles. Such economic development in combination with transitional population growth and increased population pressure tends to degrade the environment. However, it may be wrong to assume that economic development necessarily brings environmental degradation. This may be true only if technology, people's tastes, and environmental investments are not changing. A rapidly degrading or highly degraded environment can adversely affect the social and economic development. This negative effect of environmental degradation on development can be magnified by increasing population pressure. A rapidly degrading or highly degraded environment can also affect the demographic processes in a society.

Can "proper policies" and "better technologies" in the developing countries tackle all problems related to population growth and environment? It is certainly possible to have good developmental and environmental policies in all countries and most efficient technologies made available to the poor developing countries striving to industrialize. But how realistic are these possibilities remains an open question. The reality is very different. The fact is that, in most likelihood, the world population would double by the mid-21st century but in most poor developing countries it would triple or quadruple (United Nations 1991). The land and other vital life-support systems in most developing countries are rapidly degrading (WRI 1994). According to the *World Development Report 1992*, "even under fairly

[4] Given these problems, a better categorization of environmental dimensions, particularly with a better nomenclature for "local," "regional," and "global," is needed.

hopeful assumptions about economic recovery in the rest of the decade, the absolute number of poor in the world at the turn of the century will probably be higher than in 1985" (World Bank 1992, p. 30). Despite all local and international efforts, the poor distribution of resources and poverty levels are persisting in most countries.

Given these facts, even though the proposed theory presents an optimistic viewpoint, it is likely that in most developing countries the process of rapid environmental degradation will continue despite global concerns and increased awareness about environmental issues, until the demographic transition is completed and some reasonable standard of living is achieved. This may be due to growing population and increasing needs for goods and services that are produced through increased industrialization, increasing consumption patterns in the desire to improve standards of living, the lack of capability to introduce more expansive environmental protection measures and more efficient technology, and the lack of cleanup and rehabilitation of degraded sites. The increased awareness and concerns about environmental problems may help reduce the rate of environmental degradation to some degree. The theory, therefore, indirectly assumes that a faster decline of fertility is helpful in controlling environmental degradation and fostering sustainable development in the developing countries.

The theory hypothesizes that the demographic transition achieved at lower levels of economic development is better for the environment. This is mainly because a higher level of economic development tends to be associated with higher consumption patterns and more luxurious lifestyles. Adding one person with low consumption has a smaller environmental impact than adding a person with high consumption. The demographic transition can be achieved by equitably investing in health and education of people (the province of Kerala in India, Sri Lanka, and Mauritius are good examples). In 1992 Al Gore and the Prince of Wales both cited Kerala, India, as a stunning success story, a case of completed demographic transition without attaining a high economic development level. Speaking for sustainable development, they have suggested that the rest of the world should learn from the Kerala model in attaining good quality of life and stabilizing population growth. According to the *World Development Report 1992,* improving education for girls may be the most important long term environmental policy (World Bank 1992). Evidently, in most of the newly industrialized countries[5] (NICs) and the rapidly industrializing countries[6] (RICs), improvements in education, health, and improved access to resources, such as land, played a central role in stimulating rapid development and speeding demographic transition (WRI 1994). To meet this end, governments in developing countries need to shift their priorities somewhat. The proposed theory argues that in developing countries major emphasis should be placed upon more equitable human development, in addition to effective implementation of family planning programs, as a strategy to environmental protection.

In general, social and economic development leads to mortality and fertility decline. However, social and economic development is not a precondition to decline in either mortality or fertility. This is more so in the case of mortality. In many countries of the world, mortality has declined considerably in the post-World War II period due to imported public health technology, while in some countries, strong family planning programs have resulted in sizable declines in fertility without significant improvements in socioeconomic conditions. On the basis of their demographic transition experience, the countries of the world can be divided into three broad groups. The first group consists of those countries where declines in mortality were gradual and were followed by a relatively faster fertility decline. In such countries, demographic transition took a very long period of time and population growth rates were

[5] Newly industrialized countries include the four "tigers" of Asia: South Korea, Taiwan, Singapore, and Hong Kong.

[6] Recently industrializing countries include, but are not limited to, Indonesia, Thailand, Malaysia, Mexico, Brazil, and Chile.

never too high. All countries in this group have already completed the demographic transition and in most of these countries income levels and standards of living are high. Many of these countries are now members of the Organization for Economic Cooperation and Development[7] (OECD). Therefore, for notational convenience, countries in this first group are labeled as OECD-type countries.

The second group consists of countries where mortality declined rapidly after World War II and this abrupt decline in mortality was accompanied by a very rapid fertility decline. Most countries in this category have either completed demographic transition or are near completion. The majority of such countries are included in the so-called newly industrialized countries (NICs) and the rapidly industrializing countries (RICs) but also include countries such as Sri Lanka, Costa Rica, Mauritius, and some central European countries which do not fall under NICs or RICs.[8] Again for simplicity reasons, countries in the second group are called "NICs and RICs-type countries."

The third and last group includes such countries where mortality did decline rapidly following World War II, but this rapid decline in mortality has not been followed by a rapid decline in fertility. In most of these countries, mortality has reached a fairly low level but fertility is either stagnating at a high level or declining very slowly. Since the majority of these countries tend to be poor, the third type of demographic transition countries are simply labeled as "poor developing countries." In these three types of countries, environmental degradation curves are likely to be different. Figure 3 presents stylized patterns in fertility, mortality, development, and overall environmental degradation in these three types of countries.

If mortality declines slowly over a long period of time and fertility declines relatively faster, as was the case in most OECD-type countries, the slow population increase tends to stimulate technological development and economic growth. The environmental degradation also tends to increase slowly without much adverse effect on the rate of economic development. However, growing population size and improving standards of living continuously raise environmental degradation due to increasingly luxurious and wasteful consumption patterns well beyond the completion of demographic transition. With considerable decline in the population growth rate combined with a certain standard of living and increasingly visible environmental degradation, usually concerns for environment conservation emerge and steps for improvement and future protection are initiated. This may begin an era of improvements in some environmental dimensions.

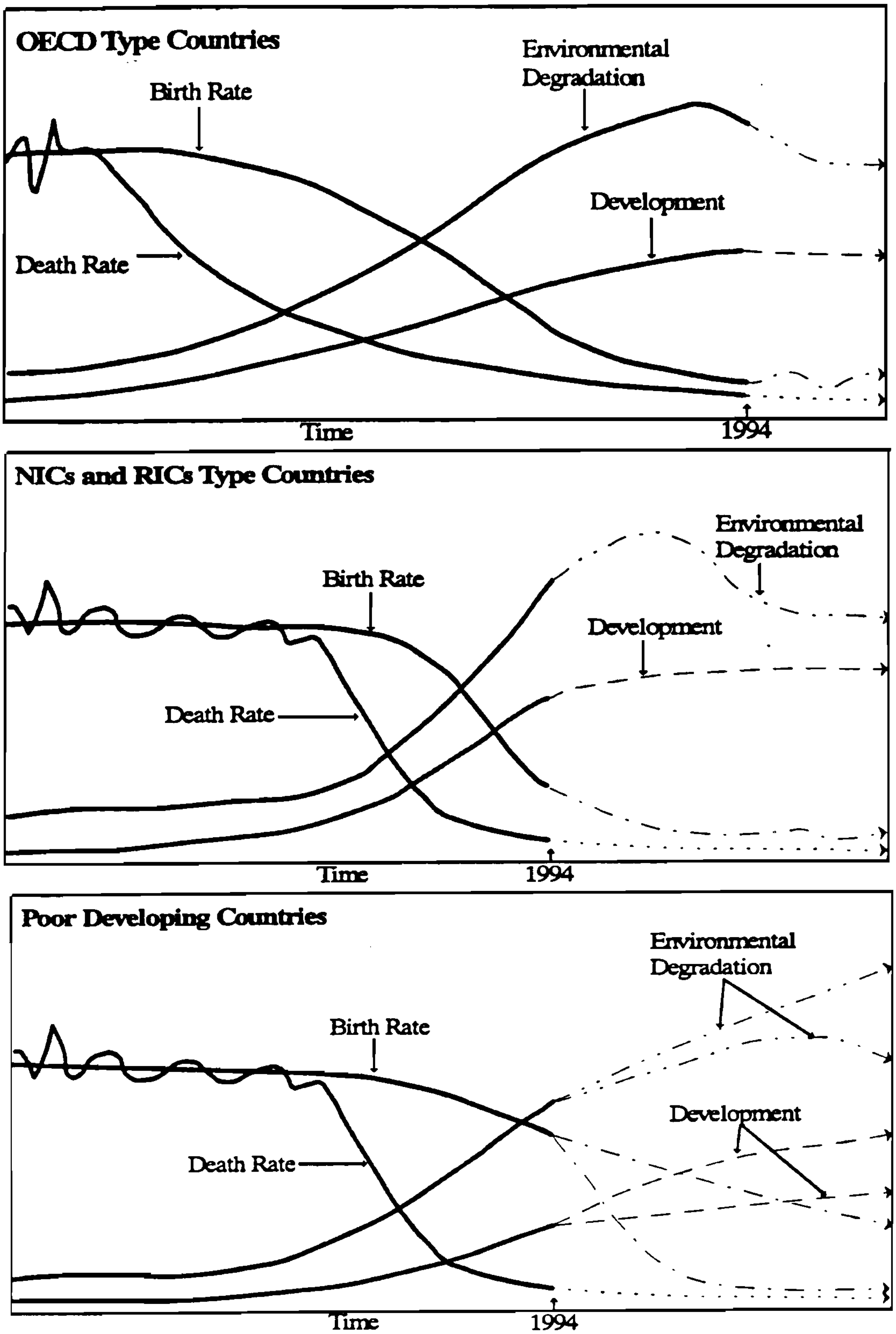
Rapid increases in population tend to make the possibility of technological stimulation difficult, disrupt slowly evolving intensification of land, adversely affect economic development, and rapidly degrade the environment (Bilsborrow and Ogendo 1992; World Bank 1992). Such effects are likely to be intensified when the resource limits of a region or country are approached. If the rapid growth of population continues for a prolonged period of time, it may cause severe damage to the environment, considerably reduce or reverse the direction of economic development, and even increase the death and birth rates temporarily. In relatively resource-poor countries these unfortunate changes are likely to happen sooner, while countries with relatively rich resource bases may be able to postpone them for some time. In general, it can be hypothesized that in developing countries, the longer the demographic transition phase, the higher the level of overall environmental degradation and slower the development.

---

[7] OECD countries include: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, United Kingdom, and United States.

[8] China is a noted exception with respect to both socioeconomic development and demographic transition. Parts of China, India, and some other developing countries may also qualify for the NICs and RICs categories (WRI 1992b).

Figure 3. Population and environment in transition.



Note: OECD stands for the Organization for Economic Co-operation and Development. OECD countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, United Kingdom, and United States. NICs stands for Newly Industrialized Countries and RICs stands for Rapidly Industrializing Countries. NICs and RICs include, but are not limited to, South Korea, Taiwan, Singapore, Hong Kong, Thailand, Indonesia, Malaysia, Mexico, Brazil, and Chile. Poor developing countries are mostly congregated in sub-Saharan Africa and South Asia with a few exceptions such as Haiti in Americas and some other countries in East and Southeast Asia.

According to the proposed theory, countries with shorter demographic transition periods are likely to experience rapid increases in the overall environmental degradation for a shorter time and the peak in the environmental degradation curve may be reached sooner than in those countries where mortality declined abruptly but fertility is either stagnating at a high level or declining very slowly. In such countries, the rapid rise in environmental degradation is likely to continue for a longer period of time.

Changes in the global environmental dimensions are likely to aggravate individual country situations and make the tasks of environmental protection, demographic transition, and development increasingly difficult at the regional to local level.

No discussion on population and environment can be complete without addressing the role of technology. Technology plays a significant mediating role between population and environment. The importance of technology in sustainable development has been repeatedly stressed. Cleaner technologies and alternative life systems in the developed countries and the transfer of cleaner technologies to the developing countries are seen as most fundamental to a cleaner, healthier, and sustainable world (Shaw 1992; World Bank 1992). Goldemberg (1992) argues that the use of advanced technology is the only answer to poverty eradication and development in poor developing countries experiencing rapid population increases. Visaria (1989) argues that the sustainable development during the 21st century, when the population is likely to continue increasing, can only be achieved through changes in technology and efficient resource use, both human and physical. However, technological development is no panacea. It is both a cause and potential remedy of environmental problems. Paul Gray (1989) calls it the "paradox of technology."

As societies modernize, often as a result of technological development, the sources of environmental degradation tend to change from traditional to modern, for example, in the case of air pollution from biofuels to fossil fuel combustion, and in the case of water pollution from poor sanitation to pesticides and other chemicals runoff. In general, one can say that technological development tends to reduce the traditional causes of environmental degradation while it increases the modern (or new) causes. In most societies, there is a period of overlap between traditional and modern sources of environmental degradation. During this overlap period, there are often significant interaction effects that can magnify or mask the effects of two types of causes (Smith 1994). Because most developing countries are in the overlap stage, the transfer of technology to the developing countries may both increase or decrease the environmental degradation in those countries. Introduction of a new technology in a country may improve some dimensions while degrading some others. While the overall impact of technology transfer to the developing countries is expected to reduce overall environmental degradation, the individual projects can have both positive and negative impacts on the environment (Smith 1994).

The production technologies now in use in most developing countries are far less efficient and more polluting than those available in the developed countries. A rapid transfer of cleaner and more efficient technologies from developed countries to the developing countries can play an important role in determining the course of economic development and environmental degradation in developing countries. As a result of progress in technology, the environmental degradation curves are expected to shift somewhat downward but overall maintaining their shape. This downward shift in environmental degradation curves may provide an opportunity for countries to develop in a less damaging manner than was possible earlier (World Bank 1992, p. 10).

5. EMPIRICAL EVIDENCE

For an empirical validation of the above ideas, long-term data for various dimensions of population, development, and environment are needed. While population and development (mainly economic) data have been compiled in many countries for a long period of time, such efforts are relatively recent for data on the environment. As a result, long-term environmental data are virtually nonexistent. However, some information on resource availability, especially land, has been compiled in many countries for centuries, mainly for administrative and revenue purposes. But detailed accounting of land use and other vital resources, such as water, air, forests, metals, and minerals, is of a very recent origin. Also, with an improved awareness about resource limitations and increased visibility of environmental degradation, many post-hoc estimations about resource availability and environmental quality have been made in recent years. The reliability of both historical environmental data and the post-hoc estimates is seriously questionable.

This paper uses some country-level data to present recent levels and trends in selected environmental dimensions with respect to income, population pressure, and human development levels around 1990. These data have been taken from the *World Development Report 1992* (World Bank 1992), *Human Development Report 1994* (UNDP 1994), World Resources Institute's *Computerized Database 1992* (WRI 1992a), and *World Resources 1992-93* and *1994-95* (WRI 1992b, 1994). Recent levels and trends in six different environmental dimensions--two in the "local" group: safe drinking water and sanitation services availability--three in the "regional" group: particulate matter concentration in urban areas, sulfur dioxide concentration in urban areas, and dissolved oxygen concentration in river water--and one in the "global" group: carbon dioxide emission from industrial sources--have been presented diagrammatically. The simple methodology used for these presentations is similar to the one used in the *World Development Report 1992* (World Bank 1992, p. 46). All the countries for which data on these six environmental dimensions were available, have been included in the analysis. The countries have been divided into three groups: low, middle/medium, and high by income, population pressure, and human development levels. The World Bank's definition of low, middle, and high income groups has been used. According to this definition, countries with per capita income less than $610, between $610 and $7,620, and more than $7,620, are categorized as low, middle, and high income countries, respectively (World Bank 1992).

The population pressure has been calculated as the product of population density and growth rate.[9] The product of population density per thousand hectare in 1990 and population growth rate during 1985-90 have been used to categorize the countries into low, medium, and high population pressure groups. The countries for which the value of the population pressure index was less than 500 have been categorized as low, between 500 and 1500 as medium, and more than 1500 as high population pressure countries.[10]

The United Nations Development Program (UNDP) categorizes countries into high, medium, and low human development groups on the basis of a human development index (HDI) which includes life expectancy, a combination of adult literacy and mean years of schooling, and standard of living measured by purchasing power parity[11] (PPP). UNDP's 1994 categorization of countries into low, medium, and high human development groups has been used in this paper (UNDP 1994).

Before discussing the levels and trends in selected environmental dimensions, it is important to mention that the indicators of the closest proximity environmental dimensions--access to safe drinking water and sanitation services in urban areas--besides representing the quality of drinking water and sanitation

[9] It would have been better to somehow include population distribution in the definition of population pressure. The distribution of population in an area is crucial in determining the population's impact on the local resources and the environment.

[10] This categorization is somewhat arbitrary. These limits were chosen because they divided all countries into roughly three equal groups. A different set of limits may change the categorization of countries into low, medium, and high population pressure groups.

[11] Purchasing power parity is estimated as real GDP per capita adjusted for the local cost of living.

conditions in cities, also represent the basic services provided by the governments mainly for better health reasons. In this sense these indicators can also be categorized as development indicators. The *1994 Human Development Report* categorizes both these close proximity environmental dimensions as indicators of human development (UNDP 1994).

The levels and trends in both access to safe drinking water and sanitation services are closely associated with the income levels of countries (see Figures 4 and 5). Almost all high income countries have attained universal accessibility to safe drinking water and sanitation services and the levels in these services in low and middle income countries are rapidly rising. The levels and trends in both dimensions by human development groups are very similar to those by income groups.

Average levels and trends by population pressure groups are consistent with the expectations. In high population pressure countries, the levels in both access to safe drinking water and sanitation services are lower than those in the low population pressure countries. It is important to note that the differences between all groups with respect to the accessibility to both services are rapidly narrowing. This reflects the concerns of local governments and international donor agencies to meet the basic needs and provide essential services to people. It is also important to note that we only see an improvement phase in both the dimensions in all groups. It appears, as hypothesized in the proposed theory, that certain environmental dimensions may not go through the deterioration phase. However, with respect to these two dimensions it may be only partially true, because looking at the country level data more closely, one can notice that in several countries, mostly very poor and rapidly growing, access to one or both safe drinking water and sanitation services declined during the 1980s (WRI 1994, pp. 274-275). It seems most likely that in these countries the local governments and donor agencies were unable to keep pace with rapidly growing urban populations. It is also possible that within a country the percentage of population with access to safe drinking water and sanitation services may increase, while the quality of drinking water and sanitation conditions may deteriorate in many urban areas.

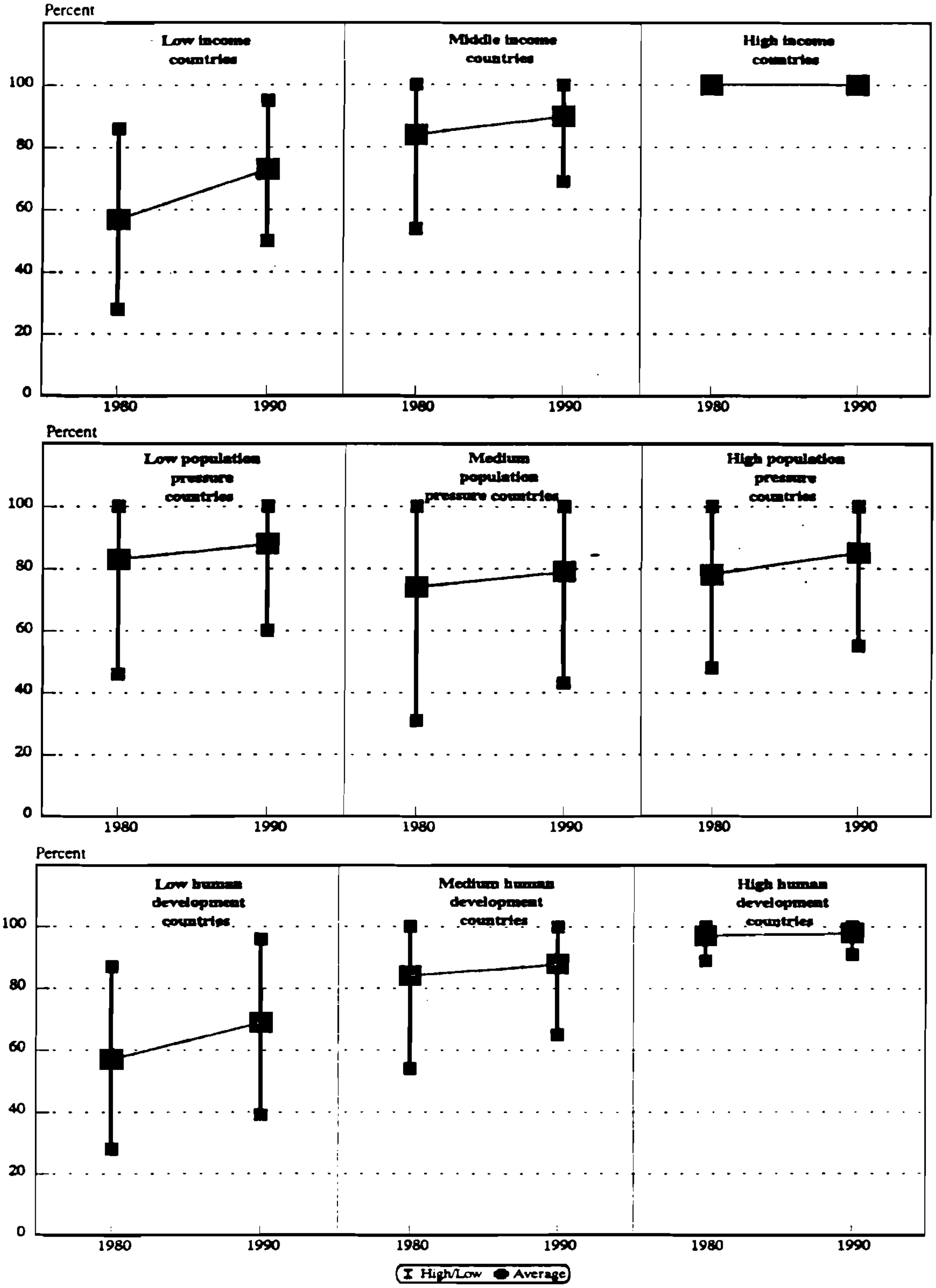
The levels and trends in both dimensions of urban air quality--annual mean concentration of suspended particulate matter and sulfur dioxide--appear to be consistent with the relationships hypothesized in the theory (Figures 6 and 7). In the cities in low income countries the air pollution levels are much higher and increasing; in the middle income countries the levels are somewhat lower and more or less stagnant; and in the high income countries the air pollution levels are considerably lower and improving.

These relationships appear to be equally powerful with respect to population pressure groups. In the low population pressure countries, on average, cities are least polluted and air quality in these cities is improving. But in the high population pressure countries, cities are heavily polluted with respect to both dimensions of urban air quality, and pollution levels in this group are further worsening. For the two urban air quality dimensions, the low human development group could not be included in the analysis due to insufficient data. However, the relationship between human development and urban air pollution appears to be constant with the theory. In the medium human development countries, the average air pollution levels are much higher and increasing, while in the high human development countries, urban air quality is improving from already much lower pollution levels. Note that even the most heavily polluted cities in the high income and low population pressure countries are less polluted than the cleanest cities in the low income and high population pressure countries. It is important to mention here that in many cities of today's high income countries, the air pollution levels have been similar or higher to those now experienced in the high population pressure and low income countries.[12] These findings clearly support the environmental transition depicted in the proposed theory along with development and demographic transition.

---

[12] For a history of air pollution in London since medieval times see Brimblecombe (1987).

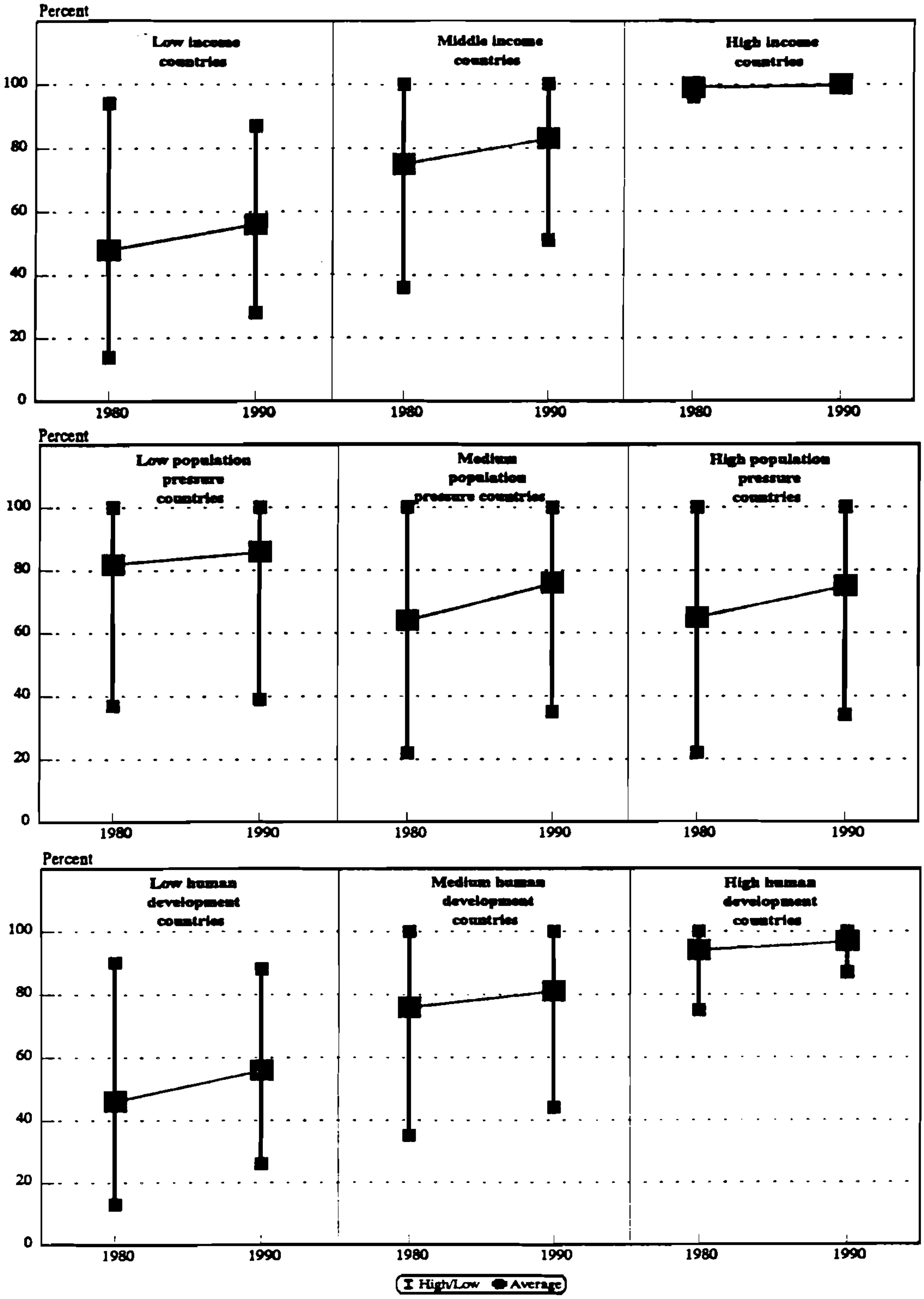
Figure 4. Levels and trends in access to safe drinking water in urban areas.



Note: Data included 131 countries. For many developed countries data were available only at one time point around the middle of the 1980s. For such countries the same figure has been used at both 1980 and 1990 time points. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth. UNDP's definition of low, medium, and high human development countries has been used. Top and bottom of bars show the countries with the highest and lowest proportion of people with access to safe drinking water represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1; WRI 1994, Table 16.4.

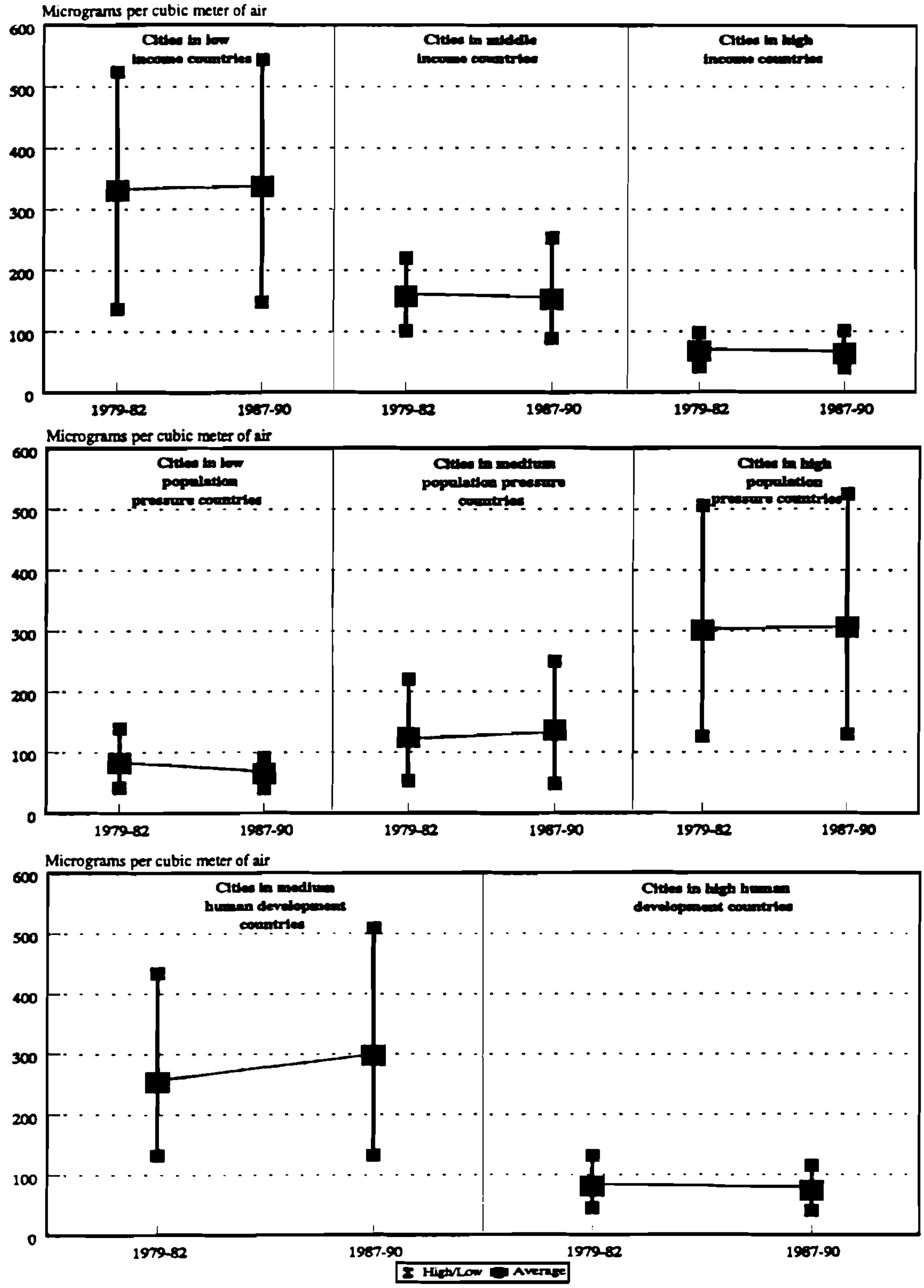
Figure 5. Levels and trends in access to sanitation services in urban areas.



Note: Data included 131 countries. For many developed countries data were available only at one time point around the middle of the 1980s. For such countries the same figure has been used at both 1980 and 1990 time points. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth. UNDP's definition of low, medium, and high human development countries has been used. Top and bottom of bars show the countries with the highest and lowest proportion of people with access to sanitation services represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1; WRI 1994, Table 16.4.

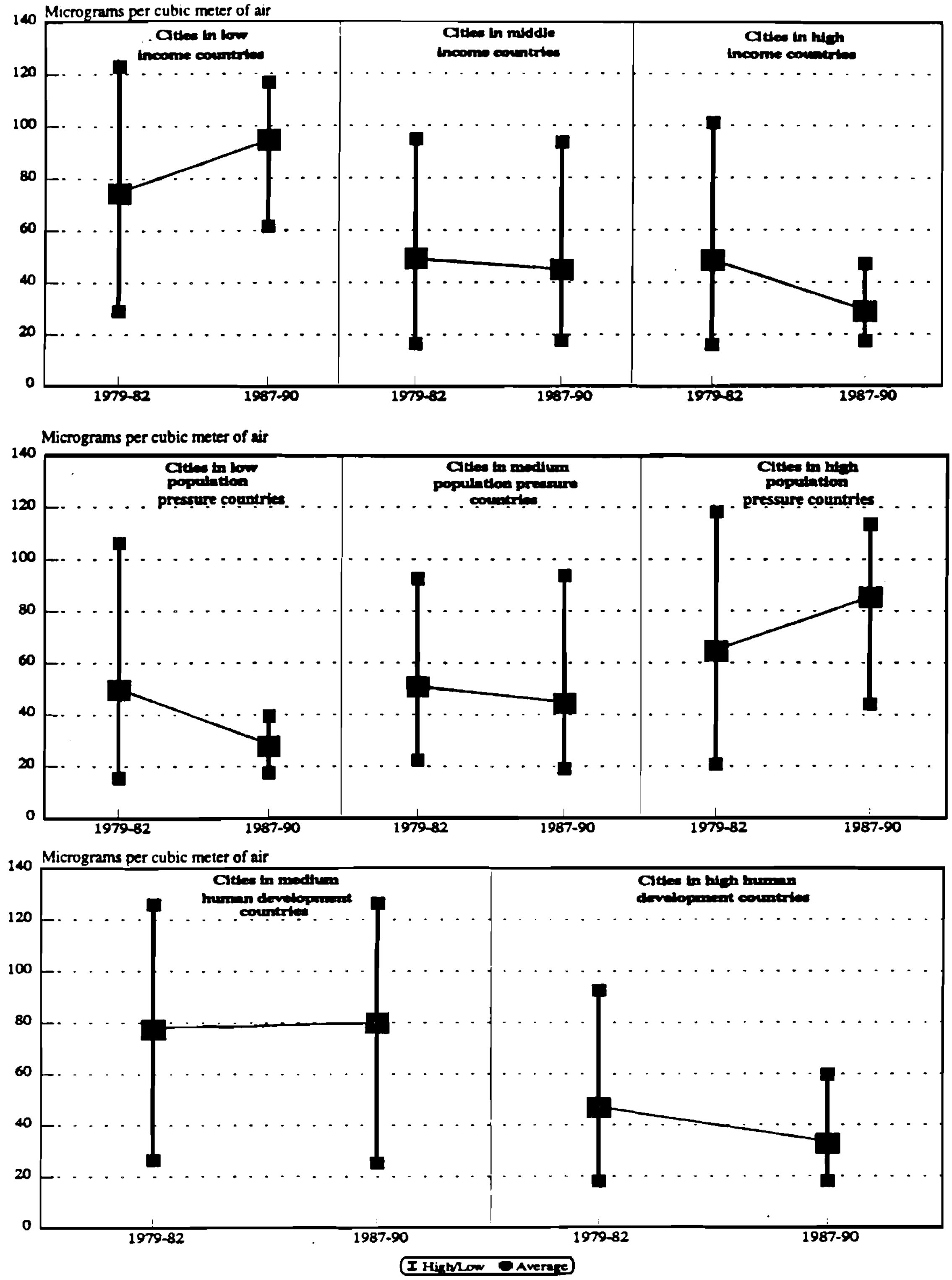
Figure 6. Levels and trends in urban air quality: Suspended particulate matter concentration.



Note: Number of observations varies from eight in the medium population pressure group in 1987-90 to 35 in the high human development group in 1979-82. Data do not necessarily correspond to the same urban sites at two time periods. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth. UNDP's definition of low, medium, and high human development countries has been used. Cities in low human development countries are not shown due to insufficient data. Top and bottom of bars show the dirtiest and cleanest urban sites represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992, Appendix Table A.5; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1.

Figure 7. Levels and trends in urban air quality: Sulfur dioxide concentration.



Note: Number of observations varies from ten in the low income group in 1987-90 to 51 in the high human development group in 1979-82. Data do not necessarily correspond to the same urban sites at two time periods. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth rate. UNDP's definition of low, medium, and high human development countries has been used. Cities in low human development countries are not shown due to insufficient data. Top and bottom of bars show the dirtiest and cleanest urban sites represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992, Appendix Table A.5; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1.

Another environmental dimension in the "regional" category--river water quality--also provides support to the proposed theory. The levels and trends in the annual mean dissolved oxygen concentration in river water present a picture similar to the two urban air quality dimensions discussed above (see Figure 8).

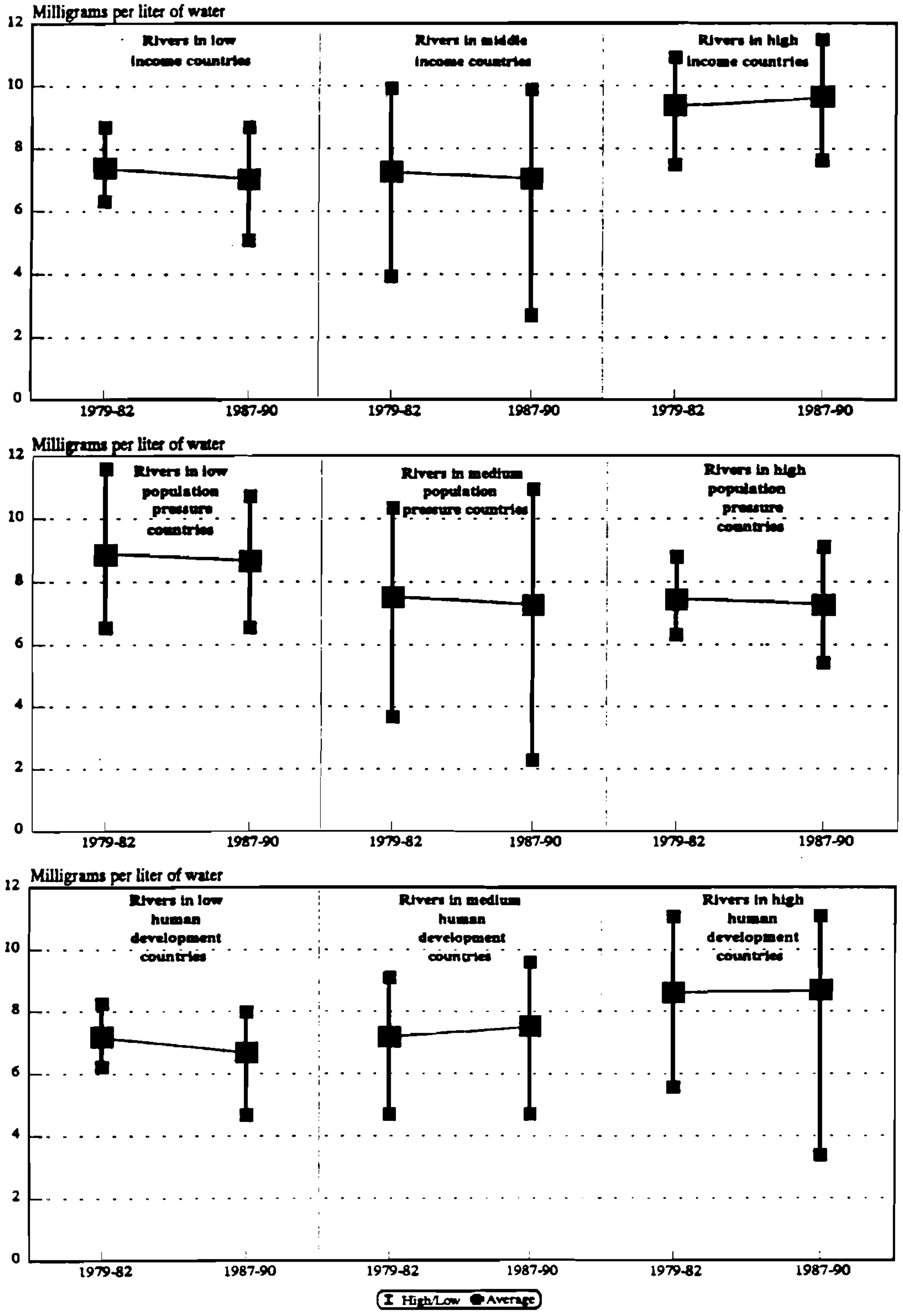
On average, the rivers in low income, high population pressure, and low human development countries have much lower dissolved oxygen levels and are more polluted than the rivers in high income, low population pressure, and high human development countries. While the river water pollution levels in high income and high human development countries are further improving, the quality of river water in low income, high population pressure, and low human development countries is deteriorating. One inconsistency in this figure is that in the low population pressure countries, the pollution levels appear to be slowly increasing. The only possible explanation for this anomaly, according to the author, could be a small number of observations on which these estimates are based.

The relationship between per capita carbon dioxide emission levels from industrial sources, an environmental dimension in the "global" category, and income is clearly most significant (see Figure 9). On average, countries in the low income group have extremely low emission levels, considerably higher in the middle income group, and extremely high for the high income countries. During the 1970s and 1980s, while the emission levels in the low income countries remained more or less static, they increased in the middle income group, and declined in the high income countries. In the middle income group, which saw an increase during this period, the per capita levels increased rather slowly during the second half of the period. The decline in carbon dioxide emission levels in high income countries could be due to improvements in technology. High income countries certainly use more efficient and less polluting technologies today than two decades ago. Moreover, many countries in the high income group have shifted from industry-based economy to service-based economy. This shift might have been partly responsible for declining per capita emission levels. Other possible reasons for this declining trend in high income countries may include composition changes in the energy sources and a shift of polluting industries to developing countries. However, the strong relationship between income and carbon dioxide emissions from industrial sources is not very surprising because high income countries are also the most industrialized countries. Even though they have better technologies of production, their consumption patterns are usually in proportion to their incomes.

Consumption patterns in the high income countries seem to overwhelm the relationship between population pressure and per capita carbon dioxide emission levels. On average, emission levels are lower in the high population pressure countries than in the low population pressure countries. This could be due to the fact that a large proportion of high population pressure countries are less industrialized and poorer and in turn have lower per capita emission levels. It is, however, important to note that in low and medium population pressure countries, per capita carbon dioxide emission levels are slowly declining, while in high population pressure countries, consistent with the proposed theory, the per capita levels are rising.

Per capita carbon dioxide levels and trends by human development groups are more in line with income groups. In low human development countries levels are very low and increasing; in the medium human development group the levels are considerably higher and more or less stagnant; and in the high human development countries the emission levels are very high but declining, particularly in the 1980s. Patterns in carbon dioxide levels by human development groups are similar to those by income groups partly because the human development indicator includes income levels and partly, to some extent, health and education levels; the other two ingredients in the indicator also depend upon the income levels of a country. However, high income levels are not a precondition for high human development levels because better health and education levels can be attained without attaining a high level of economic development.

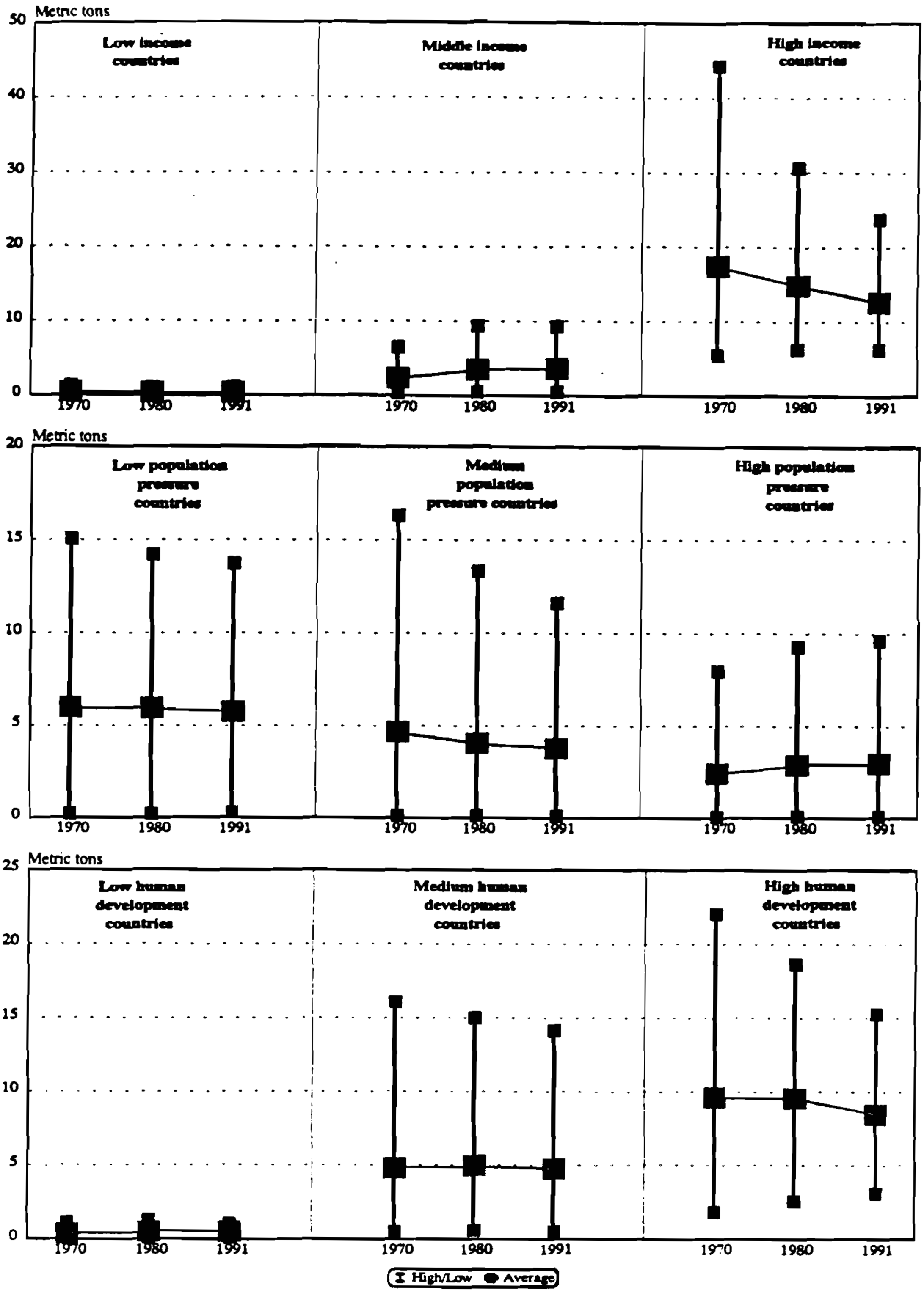
Figure 8. Levels and trends in river water quality: Dissolved oxygen concentration.



Note: Number of observations varies from 12 in the high income group in 1987-90 to 31 in the high human development group in 1979-82. Data do not necessarily correspond to the same rivers at two time periods. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth. UNDP's definition of low, medium, and high human development countries has been used. Top and bottom of bars show the cleanest and dirtiest rivers represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992, Appendix Table A.4; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1.

Figure 9. Levels and trends in per capita carbon dioxide emissions from industrial processes.



Note: Data included 147 countries. Data for 1991 included 1988 estimates for 12 countries. World Bank's definition of high, middle, and low income countries has been used. Population pressure has been defined as the product of population density and growth. UNDP's definition of low, medium, and high human development countries has been used. Top and bottom of bars show the highest and lowest per capita carbon dioxide-producing countries represented by fourth and first quartile averages, respectively.

Data Sources: World Bank 1992; UNDP 1994, Table 1; WRI 1992b, Tables 15.1, 16.1, & 17.1; WRI 1992a; WRI 1994, Table 23.1.

As can be seen from Figures 4 and 5, many low and medium income countries have attained relatively high levels of safe drinking water and sanitation services availability. Note that the differences in per capita carbon dioxide emission levels by human development groups are considerably narrower than by the income groups. It is particularly important to note that the average emission levels in the high human development group are considerably lower than those in the high income countries. This shows that it is possible to attain a high level of human development without attaining correspondingly high income levels and with a much lower environmental degradation.

The findings from the above analysis appear to be consistent, except for the environmental dimensions in the local group, with the proposition that most environmental dimensions tend to degrade to a certain level and thereafter improve before stabilizing. The results are also consistent with the proposition that the environmental dimensions in closer proximity to people tend to enter the improvement phase prior to more detached dimensions. With respect to carbon dioxide emission levels, it seems likely that the developing countries will peak at a much lower per capita level than the developed countries. The finding that per capita carbon dioxide emission levels from industrial sources are much lower in the high human development group, is consistent with the proposition that higher human development is better for the environment. The relationships between population pressure and various environmental dimensions considered above are consistent with the proposition that high population pressure has negative impact on the environment. For all the environmental dimensions, high population pressure countries have poorer environmental quality than the low population pressure countries. However, population pressure appears to be more important with respect to some environmental dimensions than others. Environmental dimensions in the regional category, i.e., those relating to the life-support systems, seem to be affected most severely by population pressure. It is important to note that there is a considerable amount of variability for all environmental dimensions within each group of income, population pressure, and human development. This variability seems to decline over time.

Numerous statements and examples in the existing literature on development and environment tend to indicate similar trends in other environmental dimensions which provide additional support for the transitions and relationships hypothesized in the proposed theory. Some of this evidence is briefly reviewed here.

Oldeman *et al.* (1990) report that in the United States and parts of Europe and Australia, soil conditions worsened till a certain level and then improved mainly as a result of government-induced soil conservation programs.

The United States Department of Agriculture (USDA), in its *Summary Report: 1987 National Resource Inventory* (1989), reports that in the United States, land suffering water-related erosion decreased from 13.6 percent to 12.6 percent during 1982 and 1987.

Water pollution trends in selected rivers in the former Czechoslovakia during 1940-80 show that the pollution levels in most rivers increased rapidly between 1940 and 1970. The pollution levels in most of these rivers peaked around 1970 and then started to decline (WRI 1992b, p. 65).

In a recent cross-sectional study of 42 major rivers, Peierls *et al.* (1991) observe a strong positive relationship between the population density of a watershed and the amount of nitrogen pollutants in the watershed's coastal area. On the basis of their findings, the authors concluded, "As the population increases, so does the pollution."

Grübler (1992), in a historical study of global land-use changes, notes that current land-use changes in many developing countries are very similar to those experienced by developed countries many decades to centuries ago. He emphasizes the role of market forces and technology over population in bringing about these changes.

Similar to Grübler, Richards (1986), in a descriptive study of historical environmental changes and economic development, observes that land transformations now widespread in many Third World countries are very similar to the experience of Western European and North American countries about a century ago. Richards is, however, somewhat skeptical about whether the recent substantial land-use and land-cover changes in the highly industrialized United States and Western Europe can be continued and replicated in the Third World countries. He recognizes the importance of population growth in land intensification and extensification, but according to Richards, market forces are more important than population in bringing about these changes.

In a recent publication, Ehrlich (1991) argues that there are limits to land intensification and land extensification. According to her, beyond a point fertilizer use, pesticide use, and irrigation all become counter-productive and in many developed countries per hectare fertilizer and pesticide use has declined in recent years.

Cho and Smith (1992) observe that the energy intensity[13] of commercial fuels in most countries first increases till a certain point and then starts to improve. Energy intensity increased in most developed countries during the second half of the 19th century and the early years of the 20th century, peaked around the second and third decades of the 20th century, and has been declining ever since. The authors further show that in most developing countries the energy intensity of commercial fuels is still increasing and is likely to peak sometime around the second or third decade of the 21st century at much lower levels than it did in the developed countries.

Ausubel *et al.* (1989) comment, "In the industrialized world, air and especially water in numerous urban areas are cleaner and safer than a century, or even a couple of decades, ago."

And the evidence goes on. Many more such examples can be found in the literature which directly or indirectly tend to support the proposed theory.

6. CONCLUDING REMARKS

This paper attempts to provide a brief overview of important theoretical ideas and outlines a conceptual framework for population and environment research. To begin with, the meanings of the terms, "population," "development," and "environment" are clarified and a basic conceptual framework, in the form of a box-and-arrow diagram, is developed. This framework differentiates the characteristics of population and environment from their processes and proximate determinants and shows underlying links between population, development, and environment. It is hoped that by conceptualizing "population," "development," and "environment" and their underlying relationships in this manner, a clear understanding of their meanings and interconnections can be achieved.

A review of the literature is presented to provide the reader with a sense of the main ideas and arguments in the field. The review, however, far from covers all important ideas, and clearly additional work is needed. After the review of literature, a macro theory of population and environment is outlined. The proposed theory attempts to integrate population, development, and environment interactions in a dynamic framework. This theory is expected to make a useful contribution to the current debate about the role of population growth in environmental degradation and shed some light on the complex and dynamic nature of interactions between population, development, and environment. According to this theory, various dimensions of population, development, and environment affect each

[13] Energy intensity is expressed as the amount of energy (in equivalent metric tons of petroleum) consumed to yield US $1,000 of gross domestic product.

other and move toward some hypothetical equilibrium state. It is hypothesized that along with modernization and demographic transition, overall environmental degradation undergoes a transition from a relatively low-stable state in the pre-transition phase to a relatively high-stable state in the post-transition phase. During the transition phase the overall environmental degradation first deteriorates and then improves before stabilizing at some level and completing the environmental transition. Recent cross-national data and evidence from other people's work provide some support for the relationships hypothesized in the theory.

It is recommended that this theoretical framework should be used simply as a broad guiding framework to understand the interrelationships between population, development, and environment and should not be used for prediction purposes. Working within the proposed theoretical framework, attempts should be made to study specific situations in detail for an in-depth understanding of population and environment interactions at appropriate levels of aggregation. The box-and-arrow diagram presented in Figure 1, if used in the light of the theoretical ideas discussed above, can be very helpful in conducting such detailed case studies and understanding population-development-environment relationships in a population.

There is a host of important issues which could not be addressed adequately within the scope of this paper. These include poverty, resource distribution, gender issues, role of governments, policies and non-governmental organizations, role of donor agencies and trade, and problems of scale. Many of these factors are included in the conceptual framework provided in Figure 1 and can play a significant role in determining the course of population, development, and environment in any society. There is mounting evidence that environmental degradation disproportionately affects women, children, and the poor. While discussing overall patterns, such important variations are hidden. These variations need to be addressed and highlighted while studying population, development, and environment linkages in a particular context. Ideas presented in the proposed theory need more thought and better organization. Further research is required to empirically test the ideas presented in the proposed theory at different levels.

REFERENCES

Ausubel, Jesse H., Robert A. Frosch, and Robert Herman. 1989. Technology and environment: An overview. Pages 1-20 in Jesse H. Ausubel and Hedy E. Sladovich, eds. *Technology and Environment.* Washington, D.C.: National Academy Press.

Bilsborrow, Richard E. 1987. Population pressures and agricultural development in developing countries: A conceptual framework and recent evidence. *World Development* 15:183-203.

Bilsborrow, Richard E. and H.W.O. Okoth Ogendo. 1992. Population-driven changes in land use in developing countries. *Ambio* 21:37-45.

Binswanger, Hans P. and Prabhu L. Pingali. 1985. Population growth and technological change in agriculture. Pages 62-89 in Ted J. Davis, ed. *Proceedings of the Fifth Agricultural Sector Symposium: Population and Food.* Washington, D.C.: The World Bank.

Blakie, P. and H.C. Brookfield. 1987. *Land Degradation and Society.* London: Methuen.

Bongaarts, John P. 1993. Population Growth and the Food Supply. Paper presented at the Population Association of America Annual Meeting, April 1-3, 1993, Cincinnati, Ohio.

Bongaarts, John P. 1992. Population growth and global warming. *Population and Development Review* 18:299-319.

Boserup, Ester. 1981. *Population and Technological Change: A Study of Long-Term Trends.* Chicago: University of Chicago Press.

Boserup, Ester. 1976. Environment, population and technology in primitive societies. *Population and Development Review* 2:21-36.

Boserup, Ester. 1965. *The Conditions of Agricultural Growth.* Chicago: Aldine.

Brimblecombe, Peter. 1987. *The Big Smoke: A History of Air Pollution in London Since Mediable Times.* London and New York: Methuen.

Bryant, Nevin Arthur. 1978. *Population Pressure and Agricultural Resources in Central Java: The Dynamics of Change.* Ann Arbor, Michigan: University of Michigan (Thesis).

Catton, William R., Jr. and Riley E. Dunlap. 1978. Environmental sociology: A new paradigm. *American Sociologist* 13:41-49.

Cho, Lee Jay and Kirk R. Smith. 1992. *Population, Cities and Environment in the Asia Pacific Region.* Honolulu, Hawaii: East-West Center.

Clark, William C. 1992. The Role of Population Growth in Environmental Degradation: Towards A Comparative Historical Analysis of Country Level Data. Paper presented at the Population and Environment Workshop of the Social Science Research Council and the International Social Science Council, January 18 - February 1, 1992, Cocoyoc, Mexico.

Cleaver, K.M. and G. Schreiber. 1992. *The Population, Agriculture and Environment Nexus in Sub-Saharan Africa.* Working Paper No. 6. Washington, D.C.: World Bank.

Coale, Ansley J. 1973. The demographic transition. Pages 53-72 in *Proceedings of the International Population Conference*, Vol. 1. Liege: International Union for the Scientific Study of Population.

Commoner, Barry. 1992. Population, Development and Environment: Trends and Key Issues in the Developed Countries. Paper presented at the United Nations Expert Group Meeting on Population, Environment and Development, January 20-24, 1992, New York.

Commoner, Barry. 1991. Rapid population growth and environmental stress. *International Journal of Health Services* 21:199-227.

Dasgupta, Partha. 1992. Population, resources and poverty. *Ambio* 21:95-101.

Davis, Kingsley. 1991. Population and resources: Fact and interpretation. Pages 1-21 in Kingsley Davis and M.S. Bernstam, eds. *Resources, Environment and Population: Present Knowledge, Future Options.* Oxford and New York: Oxford University Press.

Davis, Kingsley. 1963. The theory of change and response in modern demographic history. *Population Index* 29:345-366.

Davis, Kingsley. 1954. The world demographic transition. *The Annals of the American Academy of Political and Social Science* 237:1-11.

Drake, William D. 1984. Towards building a theory of population-environment dynamics: A family of transitions. In G.D. Ness and H. Ando, eds. *The Land is Shrinking: Population Planning in Asia*. Baltimore, MD: Johns Hopkins University Press.

Duncan, Otis Dudley. 1961. From social system to ecosystem. *Social Inquiry* 31:140-149.

Duncan, Otis Dudley. 1959. Human ecology and population studies. Pages 678-716 in Philip M. Hauser and Otis Dudley Duncan, eds. *The Study of Population*. Chicago: University of Chicago Press.

Dunlap, Riley E. and William R. Catton, Jr. 1979. Environmental sociology. *Annual Review of Sociology* 5:243-273.

Ehrlich, Ann H. 1991. People and food. *Population and Environment* 12:221-229.

Ehrlich, Paul R. and Ann H. Ehrlich. 1991. *Healing the Planet*. Reading, Massachusetts: Addition Wesley.

Ehrlich, Paul R. and Ann H. Ehrlich. 1990. *The Population Explosion*. New York: Simon and Schuster.

Ehrlich, Paul R. and Ann H. Ehrlich. 1970. *Population, Resources, Environment*. San Francisco: Freeman.

Ehrlich, Paul R. and John P. Holdren. 1971. Impact of population growth. *Science* 171:1212-1217.

English, John C. 1992. *Land Resource Management in Machakos District, Kenya, 1930-1990*. Washington, D.C.: The World Bank, Policy and Research Division, Environment Department.

Feldman, A. 1990. *Environmental Degradation and High Fertility in Sub-Saharan Africa*. Morrison Institute for Population and Resource Studies, Working Paper No. 36. Stanford, California: Stanford University.

Frisbie, W.P. and D.L. Poston, Jr. 1975. Components of sustenance organization and nonmetropolitan population change: A human ecological investigation. *American Sociological Review* 40:773-784.

Goldemberg, Jose. 1992. Energy, technology, development. *Ambio* 21:14-17.

Gray, Paul E. 1989. The paradox of technological development. Pages 192-204 in Jesse H. Ausubel and Hedy E. Sladovich, eds. *Technology and Environment*. Washington, D.C.: National Academy Press.

Grübler, Arnulf. 1992. *Technology and Global Change: Land-Use, Past and Present*. Working Paper WP-92-2. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Hardin, G. 1993. *Within Limits: Ecology, Economics and the Population Taboo*. New York: Oxford University Press.

Hardin, G. 1968. The tragedy of commons. *Science* 162:1248.

Harrison, Paul. 1992. *Third Revolution: Environment, Population and a Sustainable World*. London and New York: I.B. Tauris & Co.

Harrison, Paul. 1991. Population-Environment--Quantifying the Linkages. Paper presented at the International Union for the Scientific Study of Population, January 10, 1991, London.

Hawley, Amos H. 1986. *Human Ecology: A Theoretical Essay.* Chicago: University of Chicago Press.

Hayami, Yojiro and Vernon W. Ruttan. 1987. Population growth and agriculture productivity. Pages 57-101 in D.G. Johnson and R.D. Lee, eds. *Population Growth and Economic Development: Issues and Evidence.* Madison: University of Wisconsin Press.

Holdren, John P. 1991. Population and the energy problem. *Population and Environment* 12:231-255.

Jacobson, J. 1988. *Environmental Refugees: Yardstick of Habitability.* Washington, D.C.: Worldwatch Institute.

Kates, Robert W. and V. Haarman. 1992. Where the poor live: Are the assumptions correct? *Environment* 34:4-11/25-28.

Keyfitz, Nathan. 1992. Ecology and development: We don't know everything but we know some steps in the right direction. *Ecodecision* 7.

Keyfitz, Nathan. 1991. Population and development within the ecosphere: One view of the literature. *Population Index* 51:5-22.

Kim, Ock Kyung. 1993. Demographic patterns and wildlife resources. Pages 23-32 in *International Population Conference, August 24 - September 1, 1993, Montreal.* Liege, Belgium: IUSSP.

Kumar, Joginder. 1973. *Population and Land in World Agriculture: Recent Trends and Relationships.* Population Monograph Series No. 12. Berkeley, California: Institute of International Studies, University of California at Berkeley.

Lee, R.D. 1986. Malthus and Boserup: A dynamic synthesis. Pages 96-130 in D. Coleman and R. Schofield, eds. *The State of Population Theory: Forward from Malthus.* Oxford: Basil Blackwell.

Lele, Uma J. and Steven W. Stone. 1989. *Population Pressure, the Environment, and Agricultural Intensification: Variations on the Boserup Hypothesis.* Washington, D.C.: The World Bank.

Li, Jing Neng. 1991. Population effects on deforestation and soil erosion in China. Pages 254-258 in Kingsley Davis and M.S. Bernstam, eds. *Resources, Environment and Population: Present Knowledge, Future Options.* Oxford and New York: Oxford University Press.

Lutz, Wolfgang. 1994a. Population and environment--What do we need more urgently: Better data, better models, or better questions? Pages 47-62 in Basia Zaba and John Clarke, eds. *Environment and Population Change.* Liege: Derouaux Ordina Editions.

Lutz, Wolfgang, Ed. 1994b. *Population-Development-Environment: Understanding Their Interactions in Mauritius.* Berlin: Springer Verlag.

Lutz, Wolfgang. 1993. Population-Development-Environment: An Attempt to Set Some Basic Parameters for Analysis. Paper presented at the Population Association of America Annual Meeting, April 1-3, 1993, Cincinnati, Ohio.

Malthus, Thomas. 1960 (republished). *On Population.* New York: Modern Library and Random House.

May, John F. 1993. Policies on Population, Land Use and Environment in Rwanda. Paper presented at the Population Association of America Annual Meeting, April 1-3, 1993, Cincinnati, Ohio.

McNicoll, G. 1993. *Malthusian Scenarios and Demographic Catastrophism.* Working Paper No. 49. New York: Population Council.

McNicoll, G. 1990. *Social Organization and Ecological Stability under Demographic Stress.* Working Paper No. 11. New York: Population Council.

Meadows, Donella H., Dennis L. Meadows, and Jorgen Randers. 1992. *Beyond the Limits: Global Collapse or a Sustainable Future.* London: Earthscan Publications Limited.

Meadows, Donella H., Dennis L. Meadows, Jorgen Randers, and W.L. Behren. 1972. *The Limits to Growth.* New York: University Books.

Myers, N. 1992. Population/environment linkages: Discontinuities ahead. *Ambio* 21:116-118.

Ogburn, William F. 1922. *Social Change: With Respect to Culture and Original Nature.* New York: Viking Press.

Oldeman, L.R., R.T.A. Hakkeling, and W.G. Sombroek. 1990. *World Map of the Status of Human Induced Soil Degradation: An Explanatory Note.* Wageningen, the Netherlands: International Soil Reference and Information Center.

Park, Robert E. 1936. Human ecology. *American Journal of Sociology* 42.

Peierls, Benjamin, Nina Caraco, Michael Pace, and Jonathan Cole. 1991. Human influence on river nitrogen. *Nature* 350:386-387.

Pingali, P.L. and Hans P. Binswanger. 1987. Population density and agricultural intensification: A study of the evolution of technologies in tropical agricultural. Pages 27-56 in D.G. Johnson and R.D. Lee, eds. *Population Growth and Economic Development: Issues and Evidence.* Madison: University of Wisconsin Press.

Richards, John F. 1986. World environmental history and economic development. Pages 53-71 in W.C. Clark and R.E. Munn, eds. *Sustainable Development of the Biosphere.* Laxenburg, Austria: International Institute for Applied Systems Analysis.

Shapiro, David. 1993. Population Growth, Changing Agricultural Practices and Environmental Degradation in Zaire. Paper presented at the Population Association of America Annual Meeting, April 1-3, 1993, Cincinnati, Ohio.

Shaw, R. Paul. 1992. The impact of population growth on environment: The debate heats up. *Environmental Impact Assessment* 12:11-36.

Simon, Julian L. 1986. *The Theory of Population and Economic Growth.* New York: Basil Blackwell.

Simon, Julian L. 1981. *The Ultimate Resource.* Princeton, New Jersey: Princeton University Press.

Simon, Julian L. 1980. Resources, population, environment: An oversupply of false bad news. *Science* 208:1431-1437.

Simon, Julian L. 1977. *The Economics of Population Growth.* Princeton, New Jersey: Princeton University Press.

Simon, Julian L. and Herman Kahn. 1984. *The Resourceful Earth.* New York: Basil Blackwell.

Smil, V. 1990. Planetary warming: Realities and responses. *Population and Development Review* 16:1-29.

Smith, Kirk R. 1994. Development, health, and the environmental risk transition. In A. Binger, T. Kjellstrom, R.S. Lawrence, B. Levy, and G.B. Shahi, eds. *International Perspectives in Environment and Health* (forthcoming).

Tiffen, M. and M. Mortimore. 1992. Environment, population growth and productivity in Kenya: A case study of the Machakos District. *Development Policy Review* 10:359-387.

Turner, B.L., II and W.B. Meyer. 1991. Land use and land cover in global environmental change: Considerations for study. *International Social Science Journal* 130:669-677.

United Nations. 1991. *Long Range World Population Projections.* New York: United Nations.

United Nations Development Program (UNDP). 1994. *Human Development Report 1994.* New York: Oxford University Press.

United Nations Population Fund (UNFPA). 1991. *Population, Resources and the Environment: The Challenges Ahead.* New York.

United States Department of Agriculture, Soil Conservation Service (USDA). 1989. *Summary Report: 1987 National Resource Inventory.* Statistical Bulletin No. 790. Washington, D.C.

Visaria, Pravin. 1989. Population theory and sustainable development. *Population Bulletin of the United Nations* 27:1-29.

Winch, Donald. 1987. *Malthus.* Oxford: Oxford University Press.

World Bank. 1992. *World Development Report 1992: Development and the Environment.* New York: Oxford University Press.

World Commission on Environment and Development (WCED). 1987. *Our Common Future.* Oxford: Oxford University Press.

World Resources Institute (WRI). 1994. *World Resources 1994-95.* New York: Oxford University Press.

World Resources Institute (WRI). 1992a. *Computerized Data Base 1992.* New York.

World Resources Institute (WRI). 1992b. *World Resources 1992-93.* New York: Oxford University Press.