POPULATION AND THE ENVIRONMENT: FRAMEWORKS FOR ANALYSIS

By

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ABSTRACT

This working paper is one of a series the EPAT/MUCIA Population and Environmental and Natural Resources team is producing. It examines major ways of thinking about the population-environment relationship over the past two centuries. The paper begins with Malthus and reviews developments to the present. Then it examines in detail six current frameworks or models for analyzing population-environment relationships. The six models include Bongaarts', Clark's, and Harrison's attempts to identify the relative impact of population growth on a limited number of forms of environmental degradation. It also examines the more complex Meadows, Meadows, and Randers WORLD3 dynamic model of the global system and International Institute of Applied Systems Analysis (IIASA) population-environment model now being applied to Mauritius.

A basic finding of these models is that population growth can have a major impact on the environment. However, the impact is never simple and direct, and human organization always moderates its effect. Further, we cannot expect that slowing population growth will alleviate environmental pressures in the near term. Finally, achieving sustainable development will require a combined attack on population growth, consumption, and a variety of other human patterns of production.

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Preface

Rapid population growth is one of the most dramatic conditions of modern life. The world's population is now about 5.4 billion, and growing at just under 2% per year. Never before has the human population grown so rapidly or reached such large absolute numbers.

This growth is both good and bad news. On the positive side, it represents a major triumph over death and disease and the limits the earth might place on extracting its resources. Modern technology has kept people alive longer and in better health than ever before. It has also made human labor vastly more productive. Modern economic development, based on fossil fuels, demonstrates the success of the human species in carving out a niche for itself.

Success has a cost, however. And it may be far greater than even the most severe pessimist has imagined. Fossil fuel technology, and the human growth that it implies, constitutes a massive assault on the natural environment. Modern production and consumption greatly increase the emission of greenhouse gases into the atmosphere. This threatens to raise the earth's global temperature faster than in the past and to unprecedented levels.

Other unnatural gases, chlorofluorocarbons (CFCs), have dramatically reduced stratospheric ozone and increased ultraviolet radiation reaching the earth's surface. This threatens both human health by causing skin cancer and visual impairment and, more importantly, by affecting the food chain. Thousands of new chemicals are assaulting the earth, air, and water. Some of the new chemicals are extremely toxic and natural biological processes cannot degrade them. Finally, increased population translates into increased demand for land. Deforestation and desertification result when people invade marginal lands with technologies that degrade rather than protect the land.

Thus, there is a clear historical association between population growth and environmental degradation. The transformation to a fossil fuel technology occurred at the end of the 18th century, accompanied by development of modern urban industrial society and a substantial population increase. This occurred first in the North Atlantic countries, then spread to the rest of the world. Historically, fossil fuel consumption, urbanization and industrialization, and population growth are associated with one another.

Association is not the same as causation, however. Therefore, the question remains: what impact does population growth have on the environment? How much? In what ways? Further, what policy options are available to deal with population growth and to mitigate whatever environmental impacts it has? This paper addresses these issues.

The paper represents one of a series that the EPAT/MUCIA Population and Environmental and Natural Resources team is producing. It begins by reviewing past and current models or frameworks that show how we think about the population-environment relationship. Subsequent papers will examine what we know about this relationship in the specific areas of land use, health, women, and development. A final paper will use all of these findings to develop a specific research agenda for the future.

In this paper we make a basic argument to be carried through subsequent papers. There is no simple and direct relationship between population and environment. Identifiable forms of technology and social organization mediate impacts in both directions. It is only through these that either population or environment affect one another.

FRAMEWORKS

This paper begins our analysis of the population-environment relationship by examining a number of ways of thinking about that relationship. Whether called conceptual schemes, frameworks, models, or theories, they are all simply ideas about the relationship between population and the environment. They differ in the extent that they specify both the elements in the relationship and the linkages that bind the elements together.

There is a major problem that plagues all of these ways of thinking, and it becomes more pronounced with the elaboration of modern scientific disciplines. It has to do with what we have called a series of imbalances (Ness, Brechin, and Drake 1992) between the concepts population and environment, making it difficult to deal with them together. There are conceptual and organizational imbalances, and an imbalance in the sensitivity or negotiability of the two concepts. All of these imbalances make it difficult to think clearly and systematically about the population-environment relationship.

Conceptually, population, or more accurately, the demographic analysis of population, is relatively simple. Six variables and stable population theory permit demographers to deal with population as a condition in something like a closed system. Births, deaths, and migration constitute dynamic variables, and size, age-gender distribution, and geographic distribution are comparative static variables. These constitute a powerful set of variables, from which we can perform analyses without involving other extraneous or environmental conditions. The environment could not be more different. It is much more complex, bounded by, yet including earth, air, water and everything that connects them.

Today's population projections, reasonably accurate for the next 20 to 30 years (Lee 1991), almost totally neglect any environmental conditions or changes. For example, the current UN projections (United Nations 1990) imply that Africa's population will double from roughly 800 million to 1.6 billion by the year 2025. These projections do not take into account declining per capita cereal output, increased foreign exchange requirements for food imports, chronic warfare-induced famine, or AIDS. For developed countries and Asia and Latin America, the current projections may be valid, attesting to the power of demographic concepts and models. It is unclear how Africa, even with great assistance from the rest of the world, will be able to support 1.6 billion people.

Organizationally, there is a parallel distinction. One discipline, demography, represents population that is not closely related to any other [note 1]. But where is the environment? What discipline encompasses the environment? None, and all. Every discipline from atmospheric science and anthropology to sociology and zoology covers the environment. These disciplines have become political organizations. Gatekeepers, journals, professional meetings, language, credentials and other symbolic boundary markers maintain their artificial boundaries. The development of scientific disciplines has increased our powers of observation and understanding immensely. But these disciplines have also inadvertently worked to reduce communication among their members. Again, population has one of these disciplines. The environment has many, greatly increasing interdisciplinary communication problems.

Finally, in what we call sensitivity or negotiability, we reverse the differentials. Here, environmental issues are more simple or negotiable. They often come down to cost-benefit relationships with negotiable margins. A carbon tax can encourage people to use less fossil fuel. Bottle deposits can increase recycling. Research and development can bring cheaper, cleaner fuels. In all these cases, we can calculate the costs and benefits, often at the margins. Negotiations at the margins can lead to greater environmental protection.

Population issues are far less negotiable because they have become almost totally invested with value. Population touches on some of the primordial values human kind holds most deeply. These include race and ethnic identity, gender relations, human sexuality, and human morality. Our most fundamental human institutions, those we call religion, articulate and contain these values. We see today that Serbs, Croats, Muslims, Israelis, Palestinians, and many others, cannot bargain because they believe that their very identity is at stake. One cannot bargain away one's identity. These fundamental values, which defy rational calculation also bind up sexuality. Marguerite Halloway (1992), for example, provides a recent summary of the population controversy that surfaced and was quickly buried at the United Nations Conference on Environment and Development

(UNCED) at Rio de Janeiro in 1992.

In short, we can approach environmental issues through marginal analysis and bargaining. Population issues often deny such bargaining potential. In many ways, population issues are today highly controversial.

Despite the difficulty, thinking about population-environment relationships has been at the center of many problems confronted by modern, urban-industrial society. In this paper, we shall attempt to summarize some of the broader historical patterns of thinking in Section A on "Past Thinking." Section B concerns recent developments. We shall show how post World War II changes in world community organizations have led to greater concentration on the population-environment relationship. In addition, observation and theory in the scientific disciplines had an impact on the change of focus. Finally, Section C examines a series of recent models, based on the general framework of human ecology. These models try to grapple with the rich complexity of the population-environment relationship in a rigorous and systematic fashion.

In the final analysis, we shall make two basic points. The first is that there is no simple, direct relationship between population and the environment. No population condition or dynamic has a direct impact on the environment. Conversely, no environmental condition has a direct impact on population. All relationships between population and the environment filter through some form of technology and social organization. This argues strongly against the idea that there is any single "population problem." We shall show some evidence that "solving" the problem of rapid population growth in the developing world will not solve the problem of the population-environment relationship.

Second, we shall argue that there are some truly global problems, such as atmospheric change and the potential for global warming, or stratospheric ozone destruction. However, the population-environment relationship is, for the most, part a local or regional issue. Nations differ; even more, smaller local populations within nations differ in the pattern of their population-environment relationships. This conclusion has especially important implications for the kind of interventions USAID or the world development assistance community can design and carry out. We must make whatever models or frameworks exist for dealing with population-environment relationships relevant to specific locations. This is the only way they will be helpful in designing interventions. This calls for highly location-specific research projects and interventions.

Past Thinking

Few people will recall today that Malthus directed his famous

1798 essay, "On Population," at William Godwin. Though the essay reflected a distinctive perspective on population-environment relationships, it was even more important as a change in fundamental political philosophy. Godwin was one of the last of the 18th century rationalists. Frederick Heer (1964) called Malthus (along with Burke) one of the first great 19th century conservative philosophers.

Malthus' essay was an attack on the rationalist position that we can perfect human society. Improving the lot of humans, Malthus argued, would simply increase population growth beyond the earth's carrying capacity and lead to greater misery and mortality. In turn, this would lower population below that threshold. The essay began a long debate, splitting much of the British (and some continental) intellectual class for a generation, basically along progressive and conservative lines.

This observation is of more than academic interest. We can hear many of the elements in that great Malthus-Godwin debate today. Some have profoundly influenced population policy in some developing countries. Godwin argued for specific institutional changes to improve human life. These changes include extending the right to vote, reducing church lands, expanding education, and giving equal rights to women [note 2]. Godwin went much further, as well, working out and presenting, what has been called the first fully philosophical anarchist position. For Godwin, all institutions enslaved people and should be abolished.

Without such constraints, he argued, the human mind could work, through reason, the steps necessary to continue improving human society. Many of Godwin's proposals have, in fact, materialized.

Political and social reforms have increased equality, and population has grown along with increased human welfare. From this perspective, his vision was far more powerfully predictive than Malthus' dire predictions of doom. Godwin might well complain that few today even know his name.

Having recently discovered the magic of compound interest, Malthus found a strong argument against the rationalists' proposals [note 3]. Population has the capacity to grow by geometric progression, while food output can only grow by arithmetic progression. Thus, population would always press on the food supply. Only vice and misery could hold population in check. In subsequent editions of his essay, after he was married, Malthus discovered moral restraint and added this to the list of checks on population growth. In the 20th century, neo-Malthusians took up his concern for population growth and promoted the use of restraint. These were the forerunners of the modern birth control movement.

Esther Boserup (1965, 1981) represents an anti-Malthusian perspective that, in some sense, specifies the connection Godwin saw in more general terms. Boserup holds that, historically, population growth has pushed individuals and groups to develop new and more productive technologies to extract more resources from the environment. Malthus assumed technology, like "the passions," to be a given. Boserup observes the historical increase in the extractive capacity of human technology and proposes that the pressures of population growth have driven a great deal of the increase.

There was another line of conflict with modern repercussions as well. Marx poured caustic criticism on Malthus, arguing that the only problem was capitalism and not population growth. A communist revolution would end the slavery of private property, on which capitalism was built, and lead to a (rather Godwinian) rational adjustment of population to the land's resources. More than a century later, China's population policy showed wild swings from 1953 to 1972, as the leadership shifted from red (or revolutionary) to expert (or industrial engineer) positions, with Mao following faithfully Marx's attack on Malthus' position on population pressure. Only after Mao's fall did the expert position win to produce one of the world's most successful, and coercive, modern fertility control programs (Ness and Ando 1984).

Malthus' essay marks the beginning of two centuries of concern with the population-environment relationship. These two centuries are, however, marked by quite different positions in major patterns of thought. Until 1850, the problem was that of population growth pressing on resources, especially on land. By 1850, labor overtook land as a major development resource in the rising industrial system. Output increased greatly and reduced the fear that population growth would outrun environmental resources. For the first half of the 20th century, declining fertility led to a fear of stagnation and decline. This fear even took on a sinister character as elites saw fertility differentials develop along class lines. They feared that the higher fertility of the lower classes would lead to a diminishing quality of society. The Nazis took this fear to a bloody conclusion when they defined the issue by "race" rather than class.

One of the few to voice concern with population growth at this time was P. K. Watal, an Indian demographer. In 1917, he warned of the possibility of disastrous population pressures in India. His position, stated again in the 1930s, provided a foundation for the Congress party's policy goal of reduced fertility. This was adopted as official policy in the late 1930s. India, using this policy, became the first country to break with long standing official pronatalist policies and led the modern antinatalist policy revolution. (Ness and Ando 1984, chapter 3.)

The lines of arguments and their adoption by various classes have not been uniform, of course, and have often produced some strange bedfellows. On the role of population and its growth, for example, we find such people as Godwin, Marx, Mao, and Julian Simon holding very much the same technological-rationalist position.

Environmental thinking, especially in the form of a conservation ideology, has a similarly long pedigree (Grove 1990, 1992). The development of new exploiting technologies accompanied Western imperialism as the new industrial system required more and more natural resources. But explorers and natural scientists came along with the imperialist expansion. They brought with them a different way of seeing and thinking. As naturalists and ecologists, they saw the environmentally destructive impact of the diggers and cutters who brought the resources that the new industrial system needed. These naturalists, driven partly by romantic notions of "natural man," mobilized early sentiments for environmental protection. Some of the early environmental protection movements, reflected today in forest preserves, grew out of these forces. They also produced arguments for the protection of biodiversity that reverberate today in movements for environmental protection.

Recent Developments

Modern thinking on the population-environment relationship reflects some continuity with Malthus' original formulation of population growth and environmental stress. A number of organizational, disciplinary, and methodological developments have both advanced and retarded systematic thinking about the population-environment relationship. We must review these briefly before examining some of the more important current frameworks for dealing with the relationships. Our basic argument is that population and the many different elements that make up the environment have each developed powerful specializations. This specialization promotes the detailed analysis of each of the elements, but it also retards dealing with the interconnections among them.

Organizational Movements

Out of the violence of World War II emerged something of a new world community that was increasingly reflected in the structure of the United Nations and the growth of many new international governmental, non-governmental, and business organizations (Singer 1970, Jacobson 1984, Ness and Brechin 1988). Although it will be an oversimplification, it is possible to identify in this new world community a sequence of fundamental issues and their organizational components and to make a case for their logical connection over time.

The major issue that emerged after 1945 was world security. The UN Security Council was a major arena for articulating this issue. The coming of the cold war only intensified concern for the security issue, which dominated the world stage through the 1950s. Physical reconstruction and economic development paralleled the security issue after the war. The International Bank for Reconstruction and Development, The Economic Commission for Europe (ECE), and for Asia and the Far East (ECAFE) were important organizational reflections of these interests. There is another related development here that we should note, even though we do not have space to develop the point. The postwar move toward decolonization produced a number of new states, especially in Asia and Africa. This move stimulated intellectual and program-related interest in economic development.

By the 1960s, interest in development had increased considerably, partly legitimized by the argument that security requires greater international economic equality. This interest found a home in the United Nations Development Program (UNDP), in the Organization for Economic Cooperation and Development (OECD), and in the new foreign aid programs emerging among the major donor nations. During this period, for example, the United States was the world's leading donor of foreign aid, and the names of its aid agencies reflect the changes proposed here. We went from the Mutual Security Agency to the Technical Cooperation Agency to the Agency for International Development.

Both the successes and the failures of development assistance led directly to a concern for rapid population growth. Though there was much resistance to including population planning, especially fertility control, in the agenda of international assistance, a breakthrough finally occurred in 1965 and 1966. The U.N. Economic Commission for Asia and the Far East (now the Economic partly legitimized by the argumeand Social Commiss and the UN General Assembly in 1966 passed enabling resolutions (Symonds and Carder 1972, Ness and Ando 1984). These United Nations' resolutions legitimized including population planning in international development assistance. At the same time, the United States' decision to fund international population assistance provided the financial resources. Offices of Population appeared in foreign aid agencies. In addition, the United Nations created a trust fund in 1967 and the Fund for Population Activities in 1969. Funding for international population assistance rose slowly to $100 million (in constant 1985 dollars) from 1952 to 1968. From 1968 to 1972, funding jumped from $100 to $400 million and has remained roughly constant at that level (UNFPA 1992).

While international population planning programs and assistance moved ahead rapidly in the 1970s, concern for environmental degradation appeared on the horizon and was added, reluctantly and weakly, to the international agenda. The 1972 Stockholm conference articulated some of the issues, including the great division between more and less developed countries that persists today. It also led to the formation of the United Nations Environment Program (UNEP), providing organizational resources to support the growth of environmental interests. Many countries paralleled this effort by forming environmental protection agencies. For example, there were only 10 countries with environmental protection agencies at the time of the 1972 Stockholm conference. Today there are more than 100 (Meadows, Meadows, and Randers 1992).

Thus, over the past four decades and more, both population and environmental issues have come to occupy important and distinctive positions in the international and national policy arenas. The growth of specific organizations both marks the emergence of these issues on the policy agenda and promotes their elaboration and articulation. Disciplinary development in both theory and methodology have paralleled organizational developments.

Theoretical and Methodological Developments

Demography has occupied the position of a special scientific discipline for more than a century. In the United States, it has developed principally within sociology. However, economics and geography also have sub-disciplines that encompass demography. The International Union for the Scientific Study of Population (IUSSP) was formed around the turn of the century and represents one of the oldest international professional associations. Theoretical developments include the life tables and stable population theory, which have provided tools for population projections that now play an important role in linking population with other environmental issues. Along with these developments have come improvements in observation and data analysis technology.

Censuses have expanded greatly, especially since 1945, in both coverage and accuracy. And they have come to have a great impact on policy. The 1960-61 round of Asian population censuses, for example, was instrumental in pushing many countries to adopt modern antinatalist population policies. This was before the western world and the UN were ready to provide support for the programs that followed the policy decisions. This development was especially pronounced in India (Ness and Ando 1984, chapters 2 and 3).

In addition, the large scale area probability sample social survey was applied to population issues, and had an impact on the development of modern population programs. More specifically, the Knowledge-Attitude-Practice (KAP) survey became a standard tool. It was used both as a base-line survey and a tool for evaluating programs in all of the world's modern family planning programs. Computer technology greatly enhanced the capacities of social scientists to manipulate numbers, permitting extensive and sophisticated analyses of field observations.

In addition to these theoretical and methodological developments, there has been what can only be called a revolutionary breakthrough in contraceptive technology. The intrauterine contraceptive device (IUD), oral contraceptives, injections, and new methods of sterilization only became generally available during the 1960s. This technology is highly compatible with the developments in demography and with the organizational developments. It essentially gives governments something they can do to affect human reproduction if they make the policy decision to do so.

Both the theoretical and methodological developments, as well as the technological breakthrough, have made demography a powerful analytical tool. Together they provide a great deal of support for the extensive world of modern family planning programs that have grown to become one of the world's largest and most extensive public health interventions. These programs have had a substantial impact on human fertility and have undoubtedly hastened the decline of fertility in many less developed countries. The controversy that surrounds this statement has largely given way to consensus. Kingsley Davis' 1969 article in SCIENCE, Donald Warwick's "Bitter Pills" (1982), and Hernandez' SUCCESS OR FAILURE (1984) argued against the independent impact of national family planning programs on human fertility. These have now almost completely given way to recognizing the substantial and distinct impact such programs can have (Bongaarts, Mauldin, and Phillips 1990).

Theoretical and methodological developments in environmental issues are much more difficult to document, primarily because the environment is so many things. It is located in a great variety of scientific disciplines, including agriculture, agronomy, atmospheric sciences, biology, forestry, geography, geology, limnology, meteorology, oceanography, physics, public health, and zoology, to name just a few, plus all of the social sciences. Each of these disciplines has developed its own specialized set of theories and methods. Each has also established a set of national and international organizations that provide a political structure both binding the discipline together and cutting it off from others. For some of these disciplines, parallel national and international governmental agencies play important roles in the world of international development assistance. Many, such as agriculture, health, irrigation, industry, forestry, transportation and a variety of utilities, can point to substantial successes in the world of international development assistance. Furthermore, their organizational and technological cohesion can often protect them from embarrassment when their development projects end in failure or even disaster.

Our basic observation from this near half-century of organizational, theoretical and methodological developments is twofold. First, all of the individual disciplines have developed great powers of observation and analysis. Further, these analytical powers have often had substantial engineering potential, permitting us to intervene in human and natural processes with deliberate attempts to achieve highly specific goals. Sometimes those goals have been laudable and sometimes the inter-ventions have been successful. Second, however, the power of the disciplines has also made their practitioners unable, and often unwilling, to attend to relevant developments in other disciplines.

This is most evident across the population-environment divide. Attempts to cross the divide are few and cannot boast much success. Indonesia created a Ministry for Population and Environment a decade ago to try to link these important issues. Although headed by one of Indonesia's most intelligent leaders, Emil Salim, it is structurally weak (a state or staff ministry rather than a line or operational ministry). It can show little more than a few provincial level reports, and the creation of local academic research centers, for its years of activity. The United Nations Population Fund (UNFPA) has also supported some activities in population and environment. But, these cannot show much success, especially when compared with the impact of specialized fertility-limiting program assistance.

The most dramatic evidence of the divide between population and environment came with the 1992 United Nations Conference on Environment and Development (UNCED). Indonesia's Emil Salim argued strongly for including population issues in the UNCED preparatory meetings. Maurice Strong, UNCED's General Secretary, supported the appeal, and the UNFPA prepared an extensive document on population-environment dynamics. In the final analysis, however, UNCED almost totally ignored population issues in its public pronouncements and resolutions. Agenda 21 devotes only 15 of its 800 pages to population, in Chapter 5. This is a significant statement and its inclusion in the formal document of the Conference will certainly have important research and policy implications. But, equally telling, is the silence on the population issue in the Conference's public stance.

The UNCED experience illustrates one of the more stubborn problems in linking population and environment. In addition to the divisions sustained by scientific and organizational specialization, population issues suffer from acute political sensitivity, which we noted above, but should repeat. Ethnic, racial, and gender differences, as well as issues of human sexuality, all intrude upon population issues. All touch on some of the most fundamental human sentiments. All are embedded in religious institutions and reflect ultimate societal values. One need not search far for evidence of these deep conflicts around population issues. The fierce resistance of the Roman Catholic Church to modern forms of fertility limitation and the broad and often violent resistance to abortion testify to the depths of the conflict and the difficulties of resolution. It is easy to understand the desire of many environmental groups to stay out of this battleground.

Despite the deep divisions between population and environmental groups and disciplines, it is difficult to deny the relationship between population and environmental conditions in the real world. This empirical intrusion has led to some attempts to link the two in models and frameworks. We turn now to a brief review of some examples.

Current Attempts: Models and Frameworks

Over the past decade or two, scientists have attempted many times to develop frameworks and models for examining the relationship between population and the environment. Although they do not explicitly cite the heritage, all reflect the basic perspective developed in HUMAN ECOLOGY some decades ago (Hawley 1950, Duncan 1964). This perspective begins with the observation of a population in a territory or environment. It assumes that populations constantly interact with, adapt to and adapt their environments. In all cases, this two-way adaptation is mediated by some form of organization, and technology. (Population, Organization, Environment, and Technology form the acronym POET by which this paradigm is known in human ecology.) The argument is that all forms of life display this population-environment interaction. However, in most non-human forms, the organization and technology are genetically programmed and thus of relatively limited variability. The highly generalized nature of the human species implies that little is genetically programmed. Most forms of organization and technology are external to the organism. They have come to be highly variable in their development and equally highly visible to observers.

This general perspective can be diagrammed as shown in figure 1.

Our diagram was developed in Ness, Brechin, and Drake (1992) to deal with the current attempt to understand the population-environment dynamic. It differs slightly from the more traditional human ecology framework by specifying an outcome. But it sustains the most important aspect of the basic framework in arguing that all population-environment interactions are mediated by some form of organization and technology. That is, the most important linking arrow in this diagram is the one that is not there. This argues that:

There is no direct relationship between population and the environment. All impacts of population on the environment, or of the environment on population, are the result of the social organization and the human technology found in specific human groups.

In the following section, we review six models or frameworks, which provide good illustrations of the type of work that is currently being done. The first five models are formal statements about population-environment relations, including actual data and calculations. The first three all attempt to estimate the relative impacts of population growth, technology, and consumption on one single environmental condition. These are all simple models in that they do not consider feedback processes or linkages among the conditions that impact the environment. All of these simple models reflect the basic human ecology proposition that some form of technology and organization mediate all population-environment relationships. Even these simple models can be enlightening. In reviewing the models and frameworks, we shall make brief statements of their research implications and develop them more fully in a subsequent paper.

The fourth model is the more sophisticated, multisector dynamic model, WORLD3, used in the LIMITS TO GROWTH study published in 1972. Meadows, Meadows, and Randers recently reexamined and slightly revised the model in a new edition, BEYOND THE LIMITS

(1992). This is a very important piece of work, sure to be a common topic in environmental policy debates over the coming years. The fifth is the IIASA model, being applied to Mauritius.

This is the most developed of all the models and is probably the most appropriate for more systematic empirical research on the problem.

The sixth and final model is a sophisticated multi-sector framework, from which we can work out relations in specific sectors or arenas. In all of these multisectoral models, we can differentiate both population and environment by a number of characteristics. This will lead to much greater potential for tracing more complex connections.

After reviewing these six models, we shall make a few observations on two other important issues that emerge from the models. One concerns the issue of scale, the other concerns the character of change, which we see today as urgently needed and involving a revolutionary change in (or return to a prior and more healthy set of) human values.

Summary

Listed and described below are the six models:

1. Bongaarts 1992: estimates the relative impact of population growth, GDP/cap, energy intensity and carbon intensity on Carbon Dioxide emissions and global warming. Bongaarts considers the world as a whole, then groups countries according to those with more and less developed economies. For time horizons, Bongaarts looks into the future, from 1985 to 2100.

2. Clark 1992: also deals with the relative impact of population growth, GDP/capita, and energy intensity on Carbon Dioxide emissions. His analysis, however, examines the historical development in 12 countries over approximately the past 50 years.

3. Harrison 1992: presents a series of two sector calculations, using Commoner's 1972 approach. Like Clark, Harrison examines the relative impact of population growth, consumption, and technology on recent changes in a series of environmental conditions

4. Meadows 1992: is the updated WORLD3 model originally used in the 1972 Club of Rome's LIMITS TO GROWTH study. It has five sectors, each with a number of indicators, dynamically related to each other with a range of positive and negative feedback loops. The study runs a number of extremely enlightening, different future scenarios.

5. IIASA: (International Institute of Applied Systems Analysis) presents a multisectoral framework suggesting how multi-indicator societal, ecological, and economic subsystems are linked together. From this complex framework, a model of population and environment dynamics is developed specifically for Mauritius.

6. CIESIN: (Consortium for International Earth Science Information Network) is a multisectoral framework for the human dimensions of global environmental change. It parallels the Bretherton "wiring diagram" of atmospheric, oceanic, and terrestrial relations, which gave human activities the status of a single small black box. The new CIESIN framework has been illustratively applied to issues of sea level rise, human migration, and energy consumption.

Six Models

Bongaarts 1992

In this Population Council working paper, John Bongaarts attempts to estimate the relative impact of five conditions on Carbon Dioxide emissions and thus on global warming. The basic model he uses is:

$$T = P \times G \times E \times C + D,$$

where P (Population Size) times G (GDP/capita) produces GDP (or total economic output). GDP times E (Energy Intensity) produces Total Energy Consumption (TEC). TEC times C (Carbon Intensity: CI) produces Carbon Emission from Fossil Fuel Consumption (FFCE).

FFCE plus D (Deforestation) produces T (Total Carbon Emission Rate).

In our formulation, this amounts to examining the impact of population growth on one narrow condition of the environment, Carbon Dioxide emissions and the assumed link to global warming.

Different types of technology and organization are indicated by energy and carbon intensity.

Bongaarts drops tropical deforestation and does not specify a population component in this dimension of change. He then uses data from the Intergovernmental Panel on Climate Change (IPCC) and the Environmental Protection Agency (EPA) to make estimates of the impact of population growth on total emissions. He accepts the general assumptions of the impact of carbon emission on global warming. The model is run from 1985 to 2025 and 2100, and the global totals are separated into LDC and MDC regions.

Bongaarts calculates the population component as "the proportional reduction in the average Carbon Dioxide emission growth rate that would occur if population size is kept constant after 1985 [rather than growing as projected], and if, the projected future trends in the per capita emission rate remain unaffected" (p 17, bold added). This amounts to holding constant the general technology and organization of energy consumption and noting the difference between projected population growth and no population growth. These important qualifications and assumptions produce a very simple scenario that is useful for identifying the different potential population growth impacts in LDCs and MDCs. We can summarize the results as follows:

Table 1. Percent Contribution of Population Growth to Carbon Emission Increase

PERIOD	LDC	MDC	TOTAL
1985-2025	53%	42%	50%
2025-2100	39%	3%	22%
1985-2100	48%	16%	35%

In this model, population growth contributes substantially (50%) to world total Carbon Dioxide emissions for the near term. The impact declines markedly to 22% for the last three-quarters of the next century. More important is that the major impact of population growth comes in the LDCs after 2025. What is somewhat surprising in these estimates is the large role that population growth plays in carbon emission increases in the developed world before 2025. The explanation comes from the estimates of carbon emission increases. These are expected to be less than 1% per year in developed countries, where population growth, due to past momentum, is expected to be just under 0.5% per year. In the less developed countries, population growth is expected to be 1.56% per year between 1985 and 2025. Carbon emissions are expected to rise at 2.94% per year. Thus, in the LDCs, population growth plays a larger role, resulting in a much higher rate of carbon emissions than is expected in more developed countries.

Bongaarts runs the calculations out to 2100 to show the substantial drop in the impact of population growth in more developed countries and its sustained impact in less developed countries. We cannot consider such projections to be considered very accurate, of course. But, they are useful to point to the importance of the momentum that attends population growth. They also lead to a clear policy implication.

Clearly, reducing population growth in the LDCs could play a major role in lessening future global warming.

This is important, since, as I argue, the world has both the technology and the organizational capacity to reduce human fertility and thus population growth rates. What is lacking is the political and religious or moral resolution of the debate over the importance of reducing human fertility and population growth rates.

The Bongaarts' findings would also provide a strong justification for increasing global financial assistance to population issues if we could show that global population assistance has a significant impact on population policy formation or on fertility limitation program performance.

Unfortunately, such a linkage is impossible to demonstrate statistically at the global or regional level (Ness 1989). My own past research (in Asia) on this issue shows that the important determinants of policy formation, program performance, and fertility decline are at the national rather than the international level. Further, more recent work (Zhang, forthcoming 1994) [note 4] suggests that the dominant determinants of demographic change for all regions of the world are found at the national and local levels. Zhang also suggests that international population assistance may have only very limited impact, either on policy formation or on program performance. Finally, there is abundant anecdotal evidence that the sheer amount of international financial assistance is less important than: a) giving quality assistance and b) the political-administrative capacity of the recipient country.

Do not take this as an argument against international population assistance. It is simply a warning against expecting simple and homogeneous global level results. In addition, following our basic human ecological perspective, it suggests that international population assistance will work best if flexible and readily adaptable to local conditions of human social organization.

Clark 1992

Clark begins with the appropriately modest response, "We don't know," to the question of what have been the "large scale patterns of covariance in population and environment around the world" (p 2). He then makes a modest attempt, not at theory or model building, but at quantitative documentation of the impact of population growth and economic development on Carbon Dioxide emissions for 12 countries for about the last 50 years (generally 1925-1985). Clark looks backward for empirical relationships rather than to forward projections. He maintains that increases in understanding come from examining past events more precisely and accurately.

Clark uses Paul Ehrlich's identity as his basic framework:

$$X/A = P/A \times \$/P \times X/\$$$

where: X/A is pollution per square kilometer,
P/A is population per square kilometer
$/P is GDP/capita, and
X/$ is the pollution per unit of GDP.

This identity is transformed to a simple statement focusing on fossil fuel carbon emissions (C) that derive from the combination of population growth (P), economic production ($), and the carbon dioxide (C) produced per unit of production, or

$$C/A = P/A \times \$/P \times C/\$.$$

The countries for which Clark assembles data include: Canada, Japan, the UK, and the USA representing the highly industrialized countries; China, Poland, and the USSR, for centrally-planned economies; Brazil, India, and Indonesia for the poor developing countries; and Kenya and Zaire, for the more stagnant poor countries.

Clark produces an ingenious analysis of the relative impact over time and space of population growth, economic development, and energy intensity. A three-dimensional graph locates each of the 12 countries with respect to the relative impact of these three conditions on Carbon Dioxide emissions over the past few decades.

The bottom line of this analysis should come as no surprise but is well worth emphasizing: no single factor -- population, development, or energy intensity -- dominates changing patterns of Carbon Dioxide emissions over time and place. Each dominates at some time and place for all 12 countries. For example, since 1955, population growth has dominated in Zaire and Kenya. Economic development has dominated in Japan and China. And reductions in energy intensity have dominated in Canada and the

USA.

This represents a call for country-specific studies of population and other determinants of environmental impact or Carbon Dioxide emissions. It also suggests that interventions to protect the environment should be aimed at a variety of production and consumption patterns as well as at population growth.

It is important to note a qualification of the Bongaarts and Clark studies of the population-environment relationship. They both use only Carbon Dioxide emissions to indicate environmental degradation. Clark notes that such degradation goes far beyond Carbon Dioxide emissions, and for different forms, we can expect different relative population impacts. Population growth may have a substantial direct impact on land use changes and on the production of human wastes, but its connection to toxic or hazardous waste production may be far more tenuous.

Thus, one research suggestion emerging from these studies is to examine the impact of population growth on a variety of different forms of environmental degradation.

Harrison 1992

Harrison takes a step toward multi-country and multi-impact studies. He uses Commoner's (1972) identity, which is similar to the Erlich identity used by Clark, except that it omits the aerial denominator. For Harrison:

Pollution = Pop X Goods/Pop X Pollutant/Goods.

The Goods/Pop ratio represents consumption, and the Pollutant/Goods ratio represents technology. Thus Harrison, and Commoner before him, can estimate the relative impact of changes in population, consumption, or technology on environmental impact. They estimated changes for four types of environmental impacts for less- and more-developed countries for the past two to three decades. Table 2 summarizes Harrison's calculations.

Note that technological change reduces environmental impact on land and livestock by increasing the yields per area and animal.

It also reduces air pollution in the OECD countries by cleaning emissions. Only in fertilizer use has technology also increased environmental impacts. Note, too, that population growth exerts a substantial pressure on environmental degradation even in the more developed countries. In the case of Carbon Dioxide emissions, Harrison's calculations are not strikingly different from those of Bongaarts in that population growth currently (or for Bongaarts for the next few decades) exerts a substantial impact in both more and less developed countries.

Presenting a vision of the future, Harrison begins with the Boserup perspective that population growth drives technological change. When populations grow they ress upon their environments and cause problems of stress. These problems lead to various forms of deprivation, which lead people to develop new tools and practices to alleviate the stress. In the process, humans increase their productivity. But they also increase their impact on the environment, leading to another round of stresses and problems, which then can lead to another round of technological improvements. However, Harrison notes something that Boserup neglects. There may be important delays in the technological developments that relieve the stress. Here Harrison begins to address an issue that Meadows, Meadows, and Randers make more explicit, the problem of overshoot, which we will address shortly.

Table 2. Relative Impact of Change in Population, Consumption, and Technology on Various Forms of Environmental Change.

Environmental Change/Areas/Years	Population	Consumption	Technology
Arable Land 1961-85			
LDCs	+72%	+28%	-100%
MDC	+46%	+54%	-100%
Livestock numbers 1961-85			
LDCs	+69%	+31%	-100%
MDCs	+59%	+41%	-100%
Fertilizer use 1961-88			
LDCs	+22%	+8%	+70%
MDCs	+21%	+18%	+60%
Air Pollution change 1970-88			
OECD	+25%	+75%	-100%
Carbon Dioxide Emissions* 1960-88			
LDCs	46%	-	-
MDCs	35%	-	-

*Using population alone in what Harrison calls his "short method."

However, there is another qualification to note in all three of these studies. They all consider population as a one dimensional condition, marked by its growth rate. Further, they appear to assume that growth comes only from natural increase. They do not consider migration. This is necessary, of course, for Bongaarts' global estimates but is not for separate regional or national estimates. We can use these simple models to raise awareness of both the impact of population growth, and the limits of that impact on one aspect of global environmental change. However, the models are not very useful for more focused policy considerations. It is quite obvious, for example, that population growth from natural increase will have very different impacts on the environment than will increases due to migration.

Migration has not been included in any of these considerations and tends to emerge in environmental issues only in the case of "environmental refugees."

One research implication from this qualification is the indication to differentiate the population growth that comes from natural increase from that which comes from migration.

A second research implication calls for separating the population into a number of variable dimensions (e.g., age/gender distributions, rural/urban distributions) to note the differential impacts on various aspects of environmental change.

For this more sensitive type of analysis, we need to deal with many different dimensions of both population and the environment.

The multisectoral models permit us to do this, though even they represent only a first step.

Meadows 1992

This new study, updating the 1972 LIMITS TO GROWTH study, is certain to have a substantial impact on the world community concerned with development and the environment. Like its predecessor, it will most likely be the subject of intense, often heated, and sometimes possibly even enlightening debate. Since it is likely to be important to world thinking, we include a discussion of it here.

The authors use the same WORLD3 model used for the 1972 Club of Rome analysis, THE LIMITS TO GROWTH. The authors reviewed it and revised some of the parameters and coefficients. The model has 225 variables and makes estimates every six months from 1900 to 2100. It establishes a complex set of linkages with both positive and negative feedbacks in and between five sectors: population, agriculture (including food production, land fertility, development and loss), economy (including industrial and services output and jobs), persistent pollution, and nonrenewable resources. The authors note that it is not a complicated model because it treats all conditions globally. It does not distinguish among regions or countries nor among specific resources or pollutants.

The population variables include those affecting both the supply and demand sides of human fertility. They link life expectancy, perceived life expectancy, industrial output per capita and its relationship to family income and income expectations to desired completed family size for the demand side. On the supply side is the output of the service sector and the proportion of services allocated to family planning. They also include a series of basic demographic conditions, such as proportions in and mortality rates of four major age categories: 0-14, 15-44, 45-64, and over 64.

The environment, as in other cases, is marked by all other four sectors. Persistent pollution includes measures for both industrial and agricultural emissions and their toxicity. Nonrenewable resources includes a single gross estimate of their stocks plus the technology both to extract and to conserve those stocks. Agriculture includes land yields, the impact of air pollution, the technology for increasing land yields and protecting soil from erosion. And the economy includes all industrial output with needed capital and resources, plus the inputs into services and agriculture.

The basic driving force of the model is exponential growth in both population and capital or the economy. Both have the capacity to reproduce themselves and thus to grow exponentially.

Exponential growth provides the potential for overshoot. This excess can be avoided if signals of growth rates that will exceed environmental limits are accurate and timely, if they are perceived and acted upon, and if corrective actions are timely and effective .

Since the original LIMITS TO GROWTH proved so controversial, it is useful to state the authors' original conclusions, largely neglected in the debates of the time. They concluded that:

1) the present growth of the population and economy is unsustainable and would likely lead to a collapse or uncontrollable decline of population and industrial output in about 100 years;

2) it is possible to alter current trends and to produce the conditions of economic and ecological sustainability, and that this can be done along with providing a high quality of life for everyone; and finally

3) if society decides to aim for sustainability, the sooner it does so the better.

The slight revisions made in the model have not altered those conclusions. Current growth rates and patterns are beyond the limits and cannot be sustained. The patterns of unsustainable growth need not continue, however. But to change these patterns requires a change of human aim from economic growth to development. They argue that growth has not in the past and cannot in the future solve problems of poverty, unemployment or low living standards. We can have a better life for all, however, by focusing on sustainable development, rather than on growth.

The WORLD3 model reproduces the period 1900-1990 quite accurately, giving us an important validation. The authors then examined a large number of scenarios testing different assumptions about changing rates. Each run produces about 90,000 numbers. The authors simplify this by providing two graphs, dating from 1900 to 2100 for each scenario examined in the text.

One shows the world system, with resources, food, population, pollution, and industrial output. A second graph shows living standards, with life expectancy, food per capita, services per capita, and consumer goods per capita. None of the graphs show absolute values, and only a few year points are noted. Thus, the graphs can not be interpreted precisely. This tactic reinforces the authors' argument that these are not real or precise predictions, which they believe are not possible. They do believe, however, that the broad structure of changes is accurate and that the linkages in the model are correct. For the purposes of our analysis, some of their more important findings are as follows:

Continuing current growth patterns, or business as usual, will result in sustained growth to about 2010, with population peaking above 7 billion, followed by a major decline in population, industrial output, and standards of living starting around 2015.

Population falls to below current levels by 2100. The costs of extracting resources, increasing food production, and pollution abatement rise. Pollution and erosion reduce soil fertility, and investment cannot keep ahead of depreciation or provide for new capital goods. This leads to a decline in food production and health services, reducing life expectancy and raising the death rate.

If assumptions double the resource levels, collapse still follows, postponed by only a few years.

If we introduce four major types of technological fixes, all of which reduce pollution and increase energy efficiency, collapse still follows, again slightly delayed.

If world population growth falls to replacement level in 1995, it reaches 6 billion in 2000 and 7.4 billion in 2040. After that it declines as the costs of pollution and finding new resources rises, and industrial and food output fall.

A sustainable scenario is achieved by halting population growth, with replacement level at 1995, limiting consumer goods per capita to $350 (constant 1968 prices) [note 5], and putting into place the four major environment protection technologies used in earlier scenarios. This produces a population of 7.7 billion, with a life expectancy of 80 years, services per capita 210% above the 1990 level, enough food for everyone, or a global living standard equal to that of western Europe today. It is a system in dynamic equilibrium.

Two other scenarios are of considerable interest. Had the world limited population and industrial output and put in place the protective technologies in 1975, 20 years earlier, we would have reached dynamic equilibrium with a stable population of 5.7 billion early in the next century. We could have very high living standards for all, less stress on the environment, and resources to last far into the future.

On the other hand, if the world establishes these limits and protective technologies in 2015, 20 years later, there will be a partial collapse, or turbulence around the middle of the next century, but with the possibility of recovery. That is, there will be an overshoot of population and output beyond sustainable limits; they will decline rapidly then waver around the limits until a new equilibrium may be reached. In this scenario, population rises to 8.7 billion, then falls to 7.4 billion.

The authors acknowledge important qualifications of the study. These are not predictions, they are model runs. The authors do not believe that predictions of this precision are possible. They use the model to show the implications of current patterns of growth and to understand the requirements for sustainability.

They believe that the main linkages and parameters of the model, and its basic structure, are correct.

Furthermore, they note that the model is probably biased in an optimistic direction, because it does not take account of war, corruption, strikes, or extreme climate events. It assumes that people do their best to solve problems. All of this is quite unrealistic, of course. Greater realism, however, is found in other assumptions, especially those concerning delays. For example, they assume that once implemented, it will take 20 years for pollution abatement technology to be fully effective.

We should make one additional qualification which may increase the optimistic bias of the model. Although this is a global model, it does not incorporate any of the outputs from the Global

Circulation Models that predict a global warming (IPCC 1990, EPA 1989). Projections of greenhouse gas emissions show a doubling of Carbon Dioxide by the middle of the next century, with continued increases thereafter. From this, predictions of global warming of between 1 and 4 degrees Celsius are made. These global projections cannot be resolved to regional levels sufficiently small to provide much assistance in predicting the impact of warming on land use or economic activities. It is likely to affect the temperate regions more than the tropics. Many currently productive agricultural areas may face increased warming and drying. Nor does WORLD3 include potential impacts of ozone destruction, which can be expected to have deleterious effects on human health, and probably on food production as well [note 6]. If any of these scenarios prove to be valid, the demands for change in the Meadows models will be much greater. And the extent and character of the collapses without these changes undoubtedly will be more extreme.

For our purposes, perhaps the most important conclusions are:

Current patterns of population and industrial growth are not sustainable.

Technological environmental protection fixes alone will not prevent collapse.

Halting population growth alone will not avert collapse.

Sustainability can be achieved at high standards of living for all the world's current population and more.

Achieving sustainability will require limiting both population and industrial growth and putting in place a wide range of environmentally protective technologies.

IIASA

The International Institute of Applied Systems Analysis has undertaken a wide range of sophisticated studies of environmental changes, and much of this includes population activities [note 7].

The IIASA basic framework is one of a Socio-ecological system (figure 1 in Appendix), with three major sub-systems: Societal, Ecological, and Economic. It contains 40 distinct boxes of variables or conditions, such as population size and structure, quality of life, capital stock, pollution, and quality of the natural environment. These are linked through a great variety of direct and indirect connections, all of which can be specified.

From this general framework, IIASA developed a model of population-environment dynamics for Mauritius (Appendix, figure 2). This has five modules, each of which contains a specific set of measures relevant to Mauritius. All are linked together in either prescribed ways ("hard wired") or are left to the analyst to prescribe. The modules include population, economy, water, land use, and policy. The population module is a "multi-state population projection module with seven specified stages" (Lutz 1991: 14). It includes age and gender distributions, educational attainment, labor force participation, and migration. The environment is specified in two modules, for land use and for water. In all cases, the specific modules, their elements and the linkages within and between modules are developed specifically for Mauritius. The model is set up to run five-year equilibrium states from 1990 to 2050 but also has data from 1960 to 1990. This is both to validate the model and to show what would have been the conditions had Mauritius not experienced the widespread fertility decline that has brought it to the conclusion of its demographic transition.

To date (September 1992), a number of working papers (Lutz 1990, Pandit 1990, Prinz 1992) examine a variety of population and development scenarios for the future, past demo-graphic changes, and the character of labor force changes. Although Mauritius is a small island nation, its rapid demographic and economic change over the past three decades offers considerable encouragement for those seeking to promote sustainable development. In the span of just 30 years, it went through a demographic transition. It changed from a poor, agricultural, newly-independent nation with high rates of unemployment and import-substitution policies. Mauritius is now a low-fertility, fully-employed society with good future prospects for sustained development. The application to Mauritius demonstrates the real utility of the IIASA Population-Environment model. We can use the model to understand

the character of past changes and to chart the future according to a wide variety of assumptions in an exercise that has important implications for local policy.

This type of framework application and model building has a great deal to recommend it, especially for designing specific interventions. It shares much of the complexity found in the Meadows global model, but it is location specific and of direct use for policy and planning. It selects specific modules for the relevance to the specific case and also selects both elements and conditions of those modules on the basis of empirical evidence. For example, in the land use module, there is a measure for "beaches." Although these constitute a very small portion of the total land area, they have high economic value. Beaches are related to tourism, one of the island's main earners of foreign exchange and likely to be of growing importance.

It is also a model that reflects our basic philosophy or orientation, that population-environment relations are mediated by organization and technology. Lutz presents their model's philosophy as follows:

"...the causal linkages between changes in population size and structure and changes in the environment are far from being direct and constant over time and space. Only in minor ways does the sheer number of people directly affect the environment (such as Carbon Dioxide emissions by human breathing). The major human impacts on the natural environment depend on prevailing technologies, soils and climate, as well as patterns of culture and consumption" (Lutz 1991: 11).

I would argue that even in the connection between human breathing and Carbon Dioxide emission there is an organizational component.

The age structure of a population, for example, will have an impact on the rate of Carbon Dioxide emissions. Age structures are very much a product of human vital rates and migration, which are clearly affected by the technology and organization of the population.

Neither Lutz' nor our formulation implies that the number of people in any environment, or on the entire planet, is unimportant. Numbers and their rates of growth or decline are vital to both environ-mental conditions and to the quality of both current and future human life. These formulations do say, however, that there is no single population problem. Halting or reducing population growth rates alone will not solve the basic problem of creating a sustainable society. This is especially important since it rejects the idea, common in some circles, that the world's problem lies primarily in the population growth rates of the less developed countries. The simplistic focus on Third World population growth rates results in a level of conflict that obstructs the development of effective global solutions.

CIESIN

In 1988, Francis Bretherton (Fisher 1988) produced a "wiring diagram" showing the links between the physical climate system and biogeochemical cycles. This was part of the growing industry of research on atmospheric change that underpins the global warming perspective. (See Drennan and Chapman 1992. EPAT/MUCIA Policy Brief No. 1 reviews the atmospheric and warming processes and issues.) The Bretherton diagram traced most of the major linkages that produced climate change. It provided a road map that could be used to establish research priorities. At one edge

of the diagram is a black box, labelled human activities. These activities generate pollutants and Carbon Dioxide and have specific land use patterns that affect the terrestrial ecosystem,

a major element in the diagram. The human activities black box also receives inputs from the terrestrial ecosystem element and climate change from the element labeled atmospheric physics/dynamics.

This diagram is helpful to the atmospheric sciences community and to climate modelers. However, it raises many questions for social scientists and for interdisciplinary groups concerned with the human dimensions of global environmental change (Jacobson 1990). In 1991, a small group of social scientists met at the Aspen Global Change Institute to develop a parallel "wiring diagram" on the HUMAN DIMENSIONS OF GLOBAL ENVIRONMENTAL CHANGE (CIESIN 1992).

The CIESIN diagram has seven sets of conditions: six internal and one external. Within the system are Preferences and Expectations,

Political Systems, Factors of Production and Technology, Population, Economic System and Global Scale Environmental Processes. It is through the latter that this framework is linked to the Bretherton framework. The one external set of conditions is the Fund of Knowledge and Experience.

One interesting development in this framework is the specification of three speeds in the connecting links. Slow speeds are a century or more; moderate speeds are a generation, and fast speeds are months to a few years. All of the linkages of the elements to global environmental processes are either moderate or slow.

As yet, this is merely a framework suggesting the major elements and the linkages that should be examined. We need to understand how human activities affect, and are affected by, the climate and biogeochemical systems that Bretherton identified. To use such a framework, we must identify elements relevant to a particular problem and specify and quantify variables within those elements.

In addition, we must specify or measure the linkages, usually in the form of some change coefficient. None of this has yet been done, but the CIESIN team has developed three brief scenarios to illustrate how to translate the framework into researchable projects.

This research takes two general directions, adaptation and mitigation. That is, one can ask what changes can we expect in the world's ecosystem from the enhanced greenhouse effect and global warming. We can also ask what adaptations can we expect from the human community to these changes? One can also ask, however, what human activities are driving or "forcing" which environmental changes, and how can we alter these activities to mitigate them? The CIESIN document provides illustrations of both types of questions.

One scenario deals with the impact of sea level rise on human activities, illustrating the adaptive type of question. Another asks how a tax on fossil fuels might mitigate atmospheric forcing by reducing Carbon Dioxide emissions through changes in human production and consumption patterns.

A third scenario asks how climate change might affect human migration (figure 5 in Appendix). This is the only point at which the CIESIN framework touches directly on population issues.

Note that the question is one of adaptation not mitigation. It proposes that climate changes will change land use, especially the location and character of agriculture. Historically, the small labor intensive, subsistence farmers are most affected by this type of change. The common strategy for the farmer is to migrate in search of more opportunities. This illustration suggests that in this situation, "...birth and death rates may remain high as households diversify strategies and try to counteract rising uncertainties by increasing their number of children" (CIESIN 1992: 42). In the absence of increased agricultural opportunities, however, this would increase migration into urban areas, which might then lead to lower fertility.

All of these models provide useful observations, but they speak to different audiences and have slightly different implications.

Bongaarts, Clark, and Harrison all speak to a more general audience. They aim basically at raising awareness of both the magnitude of environmental changes and the relative impact of population growth, increasing consumption, and changing technology. They all tell us that population growth has a major impact on environmental degradation, but that it is not alone in its influence. Rising consumption also has an important impact in both more and less developed countries. Further, technological change works in both degrading and conserving ways.

It can increase environmental degradation through land clearing, deforestation, and especially through the emission of toxic substances into air, land, and water. None, however, examines the links among the various conditions that affect the environment.

That is done in the final three models. All three are concerned with the dynamic relationships among a variety of human social organizational and technological conditions. They all permit the examination of feedback processes, and both Meadows and the IIASA models actually attempt to estimate the direction and magnitude of these processes. The Meadows model deals with the entire global system, however, and thus carries fewer policy implications for any specific government. Its implications are for the global community as a whole. The IIASA model is designed specifically to be applied to individual countries. Thus, it has the greatest potential for developing policy implications for individual governments. The CIESIN model has the same potential, but it has not yet been developed in any specifically applied form.

The Issue of Scale

The frameworks and models examined here are composite national or global models. They all deal with large territories presided over by large scale political and economic organizations, resting on widely shared values. There is little attention to the micro level, the level of individual behavior. There is consequently, little attention to values and attitudes and to the relation between attitude and behavior.

Typically, as we scale up to higher and higher levels, we lose a rich array of variables, and can deal with combined atmospheric emission or population growth. As we scale down to smaller communities and to individual behavior, we add a great number of variables.

On the population side, there are extensive studies of the determinants of fertility. In these studies the large scale probability sample survey is the tool of observation and analysis. Here it is the individual who is the unit of analysis, and the range of variables has become substantial. At this level, values and attitudes, as well as contextual social, cultural, economic and political conditions come into play. The World Fertility Survey, and its successor, the Demographic and Health Survey, illustrate this type of analysis. It may be called one of the most massive social science projects ever carried out. More recently, survey research is applied to environmental values and such behavior as recycling or voting for environmental protection measures.

Unfortunately, the problem of disciplinary specialization once again arises to diminish our understanding. The fertility surveys that tell us so much about human reproduction provide no comparable information about attitudes or behaviors relevant to the environment. Similarly, studies of environ-mental attitudes and behaviors are silent on reproduction. There are also extensive studies of agricultural practices and family income, industrial work, individual and household consumption patterns, political attitudes and voting behavior. Almost none of these studies relates very much to the other or to population and environment relationships.

We do not yet have the tools to link these micro-level studies to the more global issues. However, there is good reason to propose both the extension of the micro-level studies and an increase in their interdisciplinary character. The National Research Council's GLOBAL ENVIRONMENTAL CHANGE: UNDERSTANDING THE HUMAN DIMENSION (Stern, Young, and Druckman 1990, chapter 8) includes one extensive set of recommendations for such studies. A subsequent paper in this series will discuss using the Environmental Knowledge, Attitude and Practice (EKAP) survey to build upon the very successful family planing KAP studies.

The Character of Change

Harrison's title reflects an important vision that appears now to be growing throughout the world. This is also reflected in the Meadows discussion of policy implications as they, too, speak of the coming Third Revolution. First came the agricultural revolution six to eight millennia ago. Then came the industrial revolution just two centuries ago. Together these have given the human species an unprecedented capacity to affect the global environment. The magnitude of this impact is both unprecedented and dangerous. It carries the capacity to render the entire planet unfit for human, and perhaps for all, life. Addressing the problem raised by this massive human assault on the global system will require a new, or Third Revolution. This revolution must move toward the use of cleaner energy, based on renewable resources and the limitation of human consumption.

Thus both Harrison and the Meadows see the need for a radical change in the near future if we are to build a sustainable world society. Meadows and to a lesser extent Harrison, see that this radical change will involve a change in the human spirit, or something Meadows calls visioning. This implies looking to a future that is better than the present, especially in the character of the human spirit and human values. This future must first be seen; then the vision must lead to action to realize the new aims. The list contains 16 elements of the new vision. It includes such things as social values of equity and justice with material sufficiency and security for all as well as leaders who are honest and respectful. Work must dignify rather than demean people. The list contains specific sustainable conditions for energy, agriculture, technology, political organizations, and the media.

Underlying all is the vision that the "reasons for living and for thinking well of oneself that do not require the accumulation of material things." (1992: 226) This is a call for a radical change in basic human values.

U.S. Vice President Albert Gore makes the same basic argument in his recent book, EARTH IN THE BALANCE, ECOLOGY AND THE HUMAN SPIRIT (1992). He devotes a chapter to "Environmentalism of the Spirit," which summons up basic values from many religions that speak to the need for a less materialistic set of values. He also quotes the Pope's observation that "...the seriousness of the ecological issue lays bare the depths of man's moral crisis." (1992: 263) Similarly, Gerard Piel (1992) ends his ONLY ONE WORLD: OUR OWN TO MAKE AND TO KEEP with an emphasis on value change. "As the present doubling of the population proceeds, people must accomplish the necessary reconstruction of their values and institutions. We have not much more than a century to find our way..." (1992: 328).

It might not be unusual for a political leader or a scientist-journalist to argue for a moral or ethical approach to modern problems, attempting to blend science and religion. It is not common, however, to find a scientist, especially an economist, and a theologian teaming up to write a technical book on sustainable development. Yet this is precisely what we have in the influential book by Daly and Cobb (1989), FOR THE COMMON GOOD: REDIRECTING THE ECONOMY TOWARDS COMMUNITY, THE ENVIRONMENT, AND SUSTAINABLE DEVELOPMENT. Their development of a new accounting system to correct the deplorable environmental blindness of the national income account is welcome. But, it is also part of a growing concern for the shortcomings of national income accounting (Repetto 1989, Lutz and El Serafy 1988). More radical, however, is their sustained attack on the mathematization of economics. They cite such notable figures as Nobel laureate Wassily Leontief, who said that "...econometricians fit algebraic functions...to essentially same set of data without being able to advance...a systematic understanding of the structure and operations of a real economic system" (1989: 32). If our current situation leads to this type of attack on the very technological core of scientific economics, the situation must indeed be grave.

Much more could be cited, but this should suffice to illustrate the point. There is today a sense of urgency about the population-environment relationship, which calls for a radical, revolutionary change. Much of that change must involve basic human values.

Conclusions

What can we take away from this review of past and current thinking about the population-environment relationship that we could use for current development strategies and tactics? Let me begin with an observation about two research cultures, then make four general observations. Later papers in this series will draw out more fully the research implications of these observations.

Two Research Cultures

We can identify two distinct research cultures in the area of environmental change. These have developed with different tools and are looking at two quite different aspects of the general problem of global environmental change. There is, as yet, little work to bring these two cultures together, but it is highly likely that much can be gained by a closer integration.

Atmospheric Sciences

One culture emerges largely from atmospheric sciences and climatology. Here the rise of greenhouse or trace gasses is the prominent observation. There is also extensive theoretical development suggesting that the long term result of this atmospheric forcing will be a rise in the earth's temperature. If we do experience a rise of 4 degrees Celsius over the next century or two, this may well constitute the most rapid temperature change the planet has ever experienced. The prospects for a massive impact on the human population are quite pronounced.

One result of global warming will almost certainly be a rise in the sea level. Even so, recent estimates of the extent of the rise tend to be more moderate than earlier estimates. Further uncertainty emerges from the observation that a rise in sea level from simple thermal expansion will be offset in some areas by uprising and worsened in others by lowering. In any event, the prospect of even moderate rises could produce massive upheavals and migration in such areas as Bangladesh. This could also have profound impacts on many of the world's cities.

In addition to global warming, with all of its uncertainties, atmospheric changes also imply much more certain depletion of the earth's ozone layer. This is a depletion that will continue and to which the human population will have to adapt. Even assuming the complete phasing out of the chlorofluoro-carbons, ozone depletion will continue well into the next century due to the lifetime of the gases already in the atmosphere.

There are two quite different implications of ozone depletion. It appears that most scientific attention today may be directed at the lesser of the two problems. Ozone depletion means an increase in ultraviolet radiation. This causes skin cancer and visual impairment and is receiving a great deal of attention. But ultraviolet radiation also offers the prospect of crop losses and possible destruction of phytoplankton, the base of the ocean's food chain. This indicates the need for more extensive monitoring of ultraviolet radiation and its impact on basic life structures.

Environmental Sciences

The environmental sciences have focused their attention on what can be generally called environmental degradation. This includes deforestation, desertification, species destruction, and the emission into the air, earth, and water of a series of human-produced toxic chemicals. All of these aspects of degradation have or can have an immediate deleterious impact on human life. They reduce food projection and water availability and produce substantial health hazards.

General Observations on Population-Environment Dynamics

Population Is Controversial

Population, especially fertility limitation, is a controversial issue both in the abstract and in many, though not all, specific locations [note 8]. This will often mitigate against linking population and environ-mental projects as environmentalists will often prefer to stay away from the potentially controversial population issues. One way around the controversy in population is to focus on the maternal and child health dimensions of fertility control. Even this, however, cannot always work to lessen the controversy sufficiently to bring population and environmental issues together.

Specialization Builds Barriers

Specialization in disciplines and development agencies will continue to keep population and environ-mental issues apart. It will also continue to sustain the considerable separation between different aspects of the environmental problem. We must design special interdisciplinary and interagency activities to bring population and environmental issues closer together.

No Direct Population-environment Linkage

There is no direct connection between population and the environment. All linkages, in both directions, are mediated by some form of organization or technology.

Slowing Population Growth Is no Panacea for Solving Environmental

Problems

Although growth is today one of the most dramatic aspects of the population dynamics, growth is not the only problem affecting the population-environment relationship. Slowing population growth rates, especially in the developing world, will have many beneficial effects, including improving human health and reducing environmental stress. At the same time, it is clear that slowing population growth alone will not do very much to reduce environmental stress, especially in the next decade.

The basic lesson is that both population growth and global change are joint products of the revolutionary switch to fossil fuels that has brought unprecedented increases in living standards to so many people. In effect, these population and environmental changes are the result of the human species' great successes in exploiting the environment. Here is a deep paradox. The human species may have been so successful in exploiting the environment that it will make the planet far less habitable to all forms of life. Our success is producing both atmospheric changes and environmental degradation that may drastically reduce the planet's carrying capacity for our own future generations.

As the Meadows study has shown, however, the current trends in population and economic growth are neither inevitable nor irreversible. The human species has the technological capacity to alter patterns of production and consumption and to produce higher standards of life for all people in a sustainable system.

It remains to be seen whether the human species will be sufficiently wise and well-organized to make the next revolution to sustainable society.

We shall probably know within the next two decades whether the current population-environment dynamic processes will lead to collapse or to sustainability.

APPENDIX 1

IIASA Socio-Ecological Systems Model

Source: Shaw, R., G. Gilberto, P. Weaver, and S. Oberg. 1991.

"Environment, Development and Systems Analysis." OPTIONS. Vienna, Austria: International Institute for Applied Systems Analysis (IIASA).

APPENDIX 2

IIASA Population-Environment Model for Mauritius

Source: Lutz, Wolfgang.   1991. "Population, Environment and Development: A case Study of Mauritius."   OPTIONS. Vienna, Austria: International Institute for Applied Systems Analysis (IIASA).

APPENDIX 3

CIESIN Bretherton "Wiring Diagram"

Source: Consortium for International Earth Science Information Network (CEISIN). 1992. PATHWAYS OF UNDERSTANDING: THE INTERACTIONS OF HUMANITY AND GLOBAL ENVIRONMENTAL CHANGE. Ann Arbor, Michigan: University Center.

APPENDIX 4

CIESIN Human Dimensions of Global Environmental Change Framework

Source: Consortium for International Earth Science Information Network (CIESIN). 1992. PATHWAYS OF UNDERSTANDING: THE INTERACTIONS OF HUMANITY AND GLOBAL ENVIRONMENTAL CHANGE. Ann Arbor, Michigan: University Center.

APPENDIX 5

CIESIN Framework for Climate Change and Population Migration

Source: Consortium for International Earth Science Information

Network (CIESIN). 1992. PATHWAYS OF UNDERSTANDING: THE INTERACTIONS OF HUMANITY AND GLOBAL ENVIRONMENTAL CHANGE. Ann Arbor, Michigan: University Center.

NOTES

1. Note that demography, usually closely related to and set in sociology as a distinct discipline, has become a separate discipline at the University of California, Berkeley.

2. Godwin married Mary Wollstonecraft, one of the early leaders of the women's liberation movement. Her book, A VINDICATION OF THE RIGHTS OF WOMEN, originally published in 1792, is still regarded as a classic in the modern struggle. (See Wollstonecraft 1988 for a modern review.) Their relationship and marriage was studiously arranged to protect her individual integrity. They both opposed marriage as an enslaving institution but married to protect Mary's daughter by an American adventurer. The daughter was conceived in France where the parents were both involved in post revolutionary activities.

3. Some of 18th century rationalism was worked out with great violence against the British ruling class, of which Malthus was a minor member. The American revolution used a rationalist natural law position to legitimize the revolt against authority and the separation of the colonies from the crown. In France, the crown was being destroyed and rationalist thought was being pushed to bloody conclusions. All of this greatly threatened the British ruling class and paved the way for the rise of 19th century conservative thought.

4. Qun Zhang is currently analyzing worldwide and regional data for a doctoral dissertation in Population Planning and International Health at the University of Michigan.

5. Consumer goods are estimated to be about 40% of total material industrial output. The authors use estimates of total material industrial output rather than GNP or GDP. This measurement provides a picture of real physical output less distorted by prices, which they view as "values assigned by producers and consumers who have power in the market." The 1990 level of total industrial output in 1968 prices is about $500 per capita for the world as a whole. This implies consumer goods per capita at $200.

6. One of the more serious intelligence failures to come out of current concerns with global warming is the lack of research on the effect of ultraviolet radiation on both oceanic food chains and agricultural output. Currently, every time it is measured, ozone depletion turns out to be of greater magnitude than expected. In addition, the major interest appears to be in the

cancer impact. Unfortunately, that reflects the influence of professional status and power systems rather than a more scientific assessment of what might be the most important environmental impact.

7. Nathan Keyfitz (1991) has been associated with the IIASA and has produced some good theoretical statements about the population-environment linkages.

8. In Asia (Ness and Ando 1984), population is less infused with religious significance and interpretation than in other world regions. This is part of the reason that Asia has led the Third World in adopting modern population policies and experiencing a more rapid fertility decline than other regions.

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