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DEMOGRAPHY AND THE ENVIRONMENT*

ANNE R. PEBLEY

Demographers' interest in the environment has generally been enmeshed in broader issues of population growth and economic development. Empirical research by demographers on environmental issues other than natural-resource constraints is limited. In this paper, I briefly review past demographic thinking about population and the environment and suggest reasons for the limited scope of demographic research in this area. Next, I describe more recent demographic research on the environment and suggest several newer areas for demographic research. Finally, I consider the future of research on the environment in the field of demography.

Two hundred years ago in his first *Essay*, Thomas Malthus argued that unrestrained population growth would eventually be limited by fixed natural resources (Malthus 1798). On the 200th anniversary of this *Essay*, the relationships between population growth, human welfare, and the natural environment continue to be widely debated (Livernash and Rodenburg 1998; Lubchenco 1998).

Public and scientific concerns about population and the environment have, of course, varied over time. Agricultural economist Vernon Ruttan identified three waves of social concern about the environment since World War II (Ruttan 1993). These waves, each of which focused on a different set of environmental issues, are shown in Table 1. During the second and third waves, the concerns of the previous waves were recycled. Thus, the list of potential problems has lengthened over time.

The first wave, in the late 1940s and early 1950s, centered on whether natural resources (such as land, water, and energy supplies) could sustain economic growth and food production in the face of population increase. These issues are similar to Malthus' original concerns.

The second wave, in the late 1960s and early 1970s, added another focus: the environment's ability to absorb by-products of modern technology, such as air and water pollutants, asbestos, pesticides, radioactive waste, and household waste (Ruttan 1993). This second wave was spurred in part by rising incomes in industrialized countries, which, ironically, increased demand, both for the commodities producing these detrimental by-products and for a cleaner environment.

The third wave, in the late 1980s and the 1990s, added yet another focus: changes occurring on a global scale, including acid rain, global warming, and ozone depletion. The second-wave and third-wave issues involve public goods—air, water, and the atmosphere—which have a well-known tendency toward over-exploitation. As the 1997 Kyoto Conference on Global Climate Change (UNFCCC 1998; Warrick 1998) suggests, third-wave problems will be particularly difficult to solve because they involve considerations of equity in the use of public goods among nations (DasGupta, Folke, and Maler 1994; Najam 1996).

Concern about two environmental issues not included in Ruttan's scheme has also increased over the past few decades. The first is wilderness destruction and extinction of plant and animal species (Hilborn 1990; Peters and Lovejoy 1990). Although ecologists and environmental groups are generally concerned with the well-being of both human and nonhuman species, social scientists and policymakers have usually focused on the consequences of environmental change for *human* welfare alone. Plant and nonhuman animal species and natural areas are often valued in the social science and policy communities only to the extent that they are perceived as useful or desirable to humans, now or in the future (Demeny 1991; McNicoll 1995).[1]

A second concern is changes in the ecology of microorganisms, resulting from human actions, such as forest destruction, global climate change, and the misuse of antibiotics and pesticides. Evidence of these changes includes the increasing frequency of drug-resistant bacteria and parasites, and newly emerging diseases (Ewald 1994; Levy 1998; Olshansky et al. 1997; Wilson, Levins, and Spielman 1994). These changes could have dramatic effects on human health (McMichael 1993, 1996). Changes in microorganism ecology often are not considered environmental problems per se, but they may well be part of a fourth wave of environmental concerns in the next decade.

Human activity has radically altered the earth's surface, oceans, and atmosphere, especially over the last 200 years. The nature and degree of these changes has been extensively documented (Turner et al. 1990). The effects of human ac-

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1. Of course, an exclusive focus on human welfare (including preferences for amenities such as wilderness area and biodiversity) may lead to considerably different policy choices about environmental trade-offs than a more general focus on preservation of natural environment (Livernash and Rodenburg 1998).

TABLE 1. THREE WAVES OF CONCERN ABOUT THE ENVIRONMENT

Wave	General Concern	Specific Issues
First Wave: 1940s and 1950s	Limited natural resources	Inadequate food production Exhaustion of nonrenewable resources
Second Wave: 1960s and 1970s	By-products of production and consumption	Pesticide and fertilizer use Waste disposal Noise Air and water pollution Radioactive and chemical contamination
Third Wave: 1980s and 1990s	Global environmental change	Climate change Acid rain Ozone depletion

Source: Ruttan (1993).

tivity are readily visible in satellite images taken from many miles above the earth.[2] Environmental changes have clearly improved human welfare, although the benefits have not always been distributed equally across or within societies. For example, anthropogenic (or human-induced) changes have improved the fertility of agricultural land; provided "built environments," which protect people from the elements, reduce exposure to disease agents, and allow a more comfortable way of life; and enhanced our ability to travel rapidly from one place to another. It is increasingly clear, however, that many of these changes have also brought substantial environmental costs.

According to many observers, population growth has been a (or often *the*) major cause of environmental problems (e.g., Ehrlich and Ehrlich 1990; Kates 1996; Smail 1997). In recent years, this belief has led to strong external pressure on demographers to pay more attention to the environmental consequences of demographic behavior. During the past decade, demographers published several broad theoretical treatments of population-environmental issues (e.g., Aramburu 1994; Cohen 1995a, 1995b; Davis 1991; Demeny 1991; Hogan 1992; McNicoll 1990, 1995; Panayotou 1996; Tabutin and Thiltges 1992). Yet empirical demographic research on environmental issues remains remarkably thin.[3] Until recently this empirical literature has generally focused only on first-wave issues—in other words, on limited natural resources, including land, energy supplies and food production (see Ridker 1972 for an exception). By contrast, little demographic research has been conducted on other types of environmental issues.

In this paper, I consider the history and future of demographic research on environmental issues. First, I briefly review past demographic thinking about population and the environment. Second, I suggest reasons for the limited scope of demographic research on the environment. Third, I describe questions asked and approaches used in more recent demographic research on these issues. Fourth, I suggest several newer areas for demographic research. Finally, I conclude with comments on the future of research on the environment in the field of demography.

A BRIEF HISTORY

From the time of Malthus, demographers' interest in the environment has been enmeshed in a much larger literature on population growth and economic development in nonindustrial or industrializing countries. For this reason, much of the demographic literature has focused on a specific demographic variable (population growth), a specific environmental concern (natural resources) and a specific set of countries (poor countries in Asia, Latin America, and Africa).

In the field of demography, the first wave of environmental concern contributed to a profound change in thinking about population and economic development. Before World War II, the dominant paradigm held that changes in demographic behavior (e.g., fertility and mortality) were *caused* by economic and social change that accompanied industrialization (Davis 1945; Kirk 1944; Notestein 1945). After the war, population growth rates in poor countries rose to unprecedented high levels as a result of rapid declines in mortality. These declines appeared to be caused by exogenous factors (e.g., the introduction of health technology) rather than endogenous economic and social change. Demographers became concerned that rapid population growth due to exogenous declines in mortality might, in fact, prevent the very economic development that would normally lead to fertility decline (Demeny 1988; Hodgson 1988). Hodgson (1988) argues that these concerns led to the development of a new orthodoxy in demography: that rapid population growth could

2. Satellite images for many parts of the earth are available on many websites, including: http://www.nasa.gov/, http://edcwww.cr.usgs.gov/, and http://www.noaa.gov/.

3. This assessment is based on several literature searches using *Population Index* and a review of several major English-language demography journals since 1965. Others have reached the same conclusion by different methods (Lutz 1994b; Stycos 1996).

retard development and exhaust natural resources, and that fertility control programs were necessary to stem the tide.

Much of the emphasis in the literature on population and economic development during this period was related to the effects of population growth on investments in capital, reflecting economic-development theory of the time. The fixed supply of natural resources as factors of production, however, was also a focus of attention. Coale and Hoover (1958), for example, concluded that constraints on resources (land, mineral resources, water) were unlikely to be a barrier to economic growth in India in the first 25 years of their projections, but that in the second 25-year period (from 1986 to 2011) "resource bottlenecks—particularly in agriculture—could become acute" (p. 330) if rapid population growth continued. Part of the reason was that investment in technology would be lower than if the population grew more slowly (Coale and Hoover 1958:330). Subsequently, many others produced macrosimulation models that examined, at least in part, the effects of population growth on resource depletion, including the highly criticized and sensational study *Limits to Growth* (Meadows et al. 1972) published in 1972, which forecast catastrophic consequences of rapid population growth.

For many demographers, early evidence that population growth could impede development and exhaust resources led *not* to further research on these issues but instead to extensive research on how to reduce fertility in poor countries. Papers on population, development, and resource issues continued to be published in the demographic literature (Bilsborrow 1992; Panayotou 1996; Repetto 1987, 1994; Repetto and Holmes 1983; Ridker 1972) and in the economic-development literature (see Robinson and Srinivasan 1997 for a review). But Kingsley Davis (1991:2) spoke for many demographers, when he said that

> ...despite the intense public interest in population and resources, the subject receives little direct attention from demographers. The reason is not that they regard it as unimportant, but rather they take its importance for granted....[An important motivation for efforts such as the World Fertility Survey is] an unquestioned belief that high fertility is causing too much population growth in the Third World, straining limited resources.

The assumption that population growth adversely affects economic growth and natural resources came under fire beginning in the late 1970s with the work of Julian Simon (1977, 1981). Simon's view was that moderate population growth is beneficial, not detrimental, because it induces technical innovation. Furthermore, market mechanisms insure substitution away from scarcer to more abundant resources, and thus prevent resource shortages.

Partly in response to this new work, the National Academy of Sciences (NAS) formed a working group on population and economic development. The NAS report (National Academy of Sciences 1986a) was controversial and has been highly influential in demographic thinking about environmental issues (Keyfitz 1992; McNicoll 1995). The report's authors concluded that population growth can have negative effects on some types of environmental outcomes, under particular social, economic and political conditions: Renewable resources, air and water quality, the climate, and species diversity may be harmed by rapid population growth. But the existence and size of these effects depends on the efficacy and efficiency of social institutions that regulate resource use and allocate the costs of externalities (National Academy of Sciences, 1986a).

Since the publication of the NAS report in 1986, there has been a significant increase in demographic attention to environmental issues. This increased attention is primarily due to recent and persuasive scientific evidence about global environmental effects and to greater popular concern about environmental issues. Several international conferences and working groups have also stimulated publications by demographers and other social scientists. Nonetheless, the amount of empirical research remains small.

WHY ENVIRONMENTAL ISSUES HAVE NOT BEEN MORE CENTRAL

Why have environmental issues—other than natural resources—*not* been a more central focus of demographic research? First, as Kingsley Davis suggested, many demographers have taken for granted that rapid population growth imperils natural resources (and by extension, the environment). Therefore, they have focused their research on the mechanisms by which population growth could be slowed, rather than on interactions between demographic and environmental variables.

Second, other demographers, paradoxically, have come to the opposite conclusion: that the central causes of environmental problems are not demographic and therefore, are not appropriate for demographic research. A central tenet of recent social science thinking about population growth, development, and the environment (McNicoll 1990; National Academy of Sciences 1986a; Panayotou 1996) is that factors such as social institutions, the efficiency of markets, patterns of income distribution, levels of technology, and regulations are at least as important as population growth. Furthermore, any direct effects of demographic change may be muted by feedback effects, such as population growth-induced technological change (Boserup 1965, 1981; Simon 1981), institutional change (McNicoll 1990), and even fertility reduction (Lee 1987, 1997). On the other hand, Keyfitz (1992) argued that the heavy focus on the role of institutions, markets, and feedback effects has led many social scientists to the erroneous conclusion that population change has little or no role in environmental change.

Third, many environmental problems involve expertise outside the realm of demography, including biochemistry, biology, agronomy, or climatology. The use of spatial statistics, remote sensing, and geographic information systems can also be an important tool. An obvious answer to this problem is collaboration, and in recent years, several interdisciplinary studies have been conducted (e.g., Entwisle, Rindfuss, and

Walsh 1996; Gaffin, O'Neill, and Bongaarts 1996; O'Neill, McKellar, and Lutz 1998). Collaboration between natural and social scientists, however, is complicated by major differences in paradigms and assumptions, and often by mutual antagonism (Keyfitz 1992; Pickett 1993). Demographers who have tried to bridge this gap would probably share Preston's (1994:90) frustration with many natural scientists who are "too wedded to the primitive, biological model of human beings, whereby humans are distinguished from ants or seagulls only by their greater capacity for ecological destruction....[ignoring] the vast repertoire of social arrangements that humans have constructed to govern their behavior." On the other hand, demographers (and social scientists, more generally) share some of the blame: By absenting ourselves from scientific and popular debates on population and the environment in recent years, we have allowed simplistic approaches to flourish without the criticism or insight that could be provided by the results of demographic research.

Fourth, longitudinal data for local areas on environmental outcomes can be difficult or impossible to obtain. Most social science approaches to the analysis of the effects of household or individual behavior on the environment require data (preferably at several points in time) on a large number of local areas and households within those areas. For land use, satellite imagery and aerial photography now provide longitudinal data on local areas for most parts of the world. Measurement of changes in air and water pollution, solid-waste disposal, and hazardous waste at the local level is often more difficult, particularly in poor countries. For example, estimates of changes in carbon emissions (or even proxies like fossil-fuel consumption) for local geographic units (e.g., counties or municipalities) are not available for many countries. However, several new methods using remote sensing are currently under development and should provide better quality data in the next few years (H. Kroehl personal communication, February 22, 1998). Furthermore, some demographers are developing methods of collecting environmental data as part of sample surveys. Examples include (1) the Chitwan Valley Family Study in Nepal, in which William Axinn and his colleagues have collected detailed data on flora diversity, flora quality, and land use, and more limited measures of water quality (W. Axinn, personal communication July 2, 1998; Shivakoti et al. 1997); and (2) the second Indonesian Family Life Survey, in which Elizabeth Frankenberg and her colleagues have collected information about the presence of air, water, land, and noise pollution in a community-facility survey, and detailed data on the severity of smoke from recent widespread forest fires (E. Frankenberg, personal communication, July 2, 1998).

Whatever the reason, environmental issues have been peripheral to the main areas of demographic research. To the extent that demographers have analyzed environmental questions, it is generally as a subsidiary issue in analyses of population and economic development. With the third wave of environmental concern in the 1980s and 1990s, however, environmental issues have begun to receive more attention from demographers.

RECENT RESEARCH QUESTIONS AND APPROACHES

Since the late 1980s, there has been a modest, but significant increase in research by demographers on environmental issues. I do not provide a comprehensive review of recent research here (for thoughtful recent reviews, see O'Neill et al. 1998; Palloni 1994; Preston 1996). Instead, I give an overview of newer research outside the traditional demographic interest in natural resources.[4] This research has focused on three main topics: (1) greenhouse gases and air pollution, (2) land use and deforestation, and (3) environmental hazards and migration.

Greenhouse Gases and Air Pollution

Virtually all research by demographers on air pollution and greenhouse gas emissions[5] consists of macrodecomposition models of greenhouse gas emissions (Bongaarts 1992; Birdsall 1992; O'Neill et al. 1998; Preston 1996).[6] These researchers have sought to answer the question, how much of an effect on greenhouse gas production has global or regional population growth had in the past, or will it have in the future? They used an accounting identity known as *IPAT*, first proposed by two ecologists (Ehrlich and Holden 1971) to decompose environmental impact into components due to population growth and to other factors. As shown in Eq. (1), IPAT states that any given environmental impact—say, carbon emissions—is the product of three (and only three) factors: population, affluence, and technology.

$$I = P\text{ (Population)} \times A\text{ (Affluence)} \times T\text{ (Technology)}, \quad (1)$$

where I is the environmental impact, say, carbon emissions, P is population size, A is average per capita affluence generally measured as GNP or GDP per capita, and T is a measure of the level of technology in use, such as carbon emissions per unit of income. Researchers have generally used a formulation of the IPAT model, which looks at change in emissions as a function of change over time in population, affluence, and technology:

$$r_I = r_P + r_A + r_T, \quad (2)$$

where r is the growth rate for each component (I, P, A, and T).[7] The impact of each factor on the right side of the equa-

4. In particular, I exclude from this discussion studies of the relationship between population growth, natural resources, and food production (e.g., Bongaarts 1996; Dyson 1996; Lutz 1994c).

5. Many of the same gases are implicated in ground-level air pollution and global climate change, though there are some differences. Despite a recent controversy about whether greenhouse gas emissions are hazardous (Stevens 1998), the general consensus among scientists is that the potential threat posed by greenhouse warming is "sufficient to merit prompt responses..." (National Academy of Sciences 1998:1). For evidence on greenhouse gas production on global climate change, see Houghton et al. (1996), Karl, Nichols, and Gregory (1997), and O'Neill et al. (1998).

6. Macrosimulation and decomposition models have also been used by many outside of demography to examine these issues. See, for example, Dietz and Rosa (1997).

7. Eq. (2) is derived from Eq. (1) by taking natural logs of both sides of Eq. (1) and dividing by the length of time over which the change occurs (see O'Neill et al. 1998; Preston 1996).

tion is described in terms of a percentage contribution to the change in the environmental impact (e.g., the percentage contribution of population growth to emissions growth would be r_P / r_I).

The IPAT framework has many well-known problems and limitations, which can produce serious biases (Deitz and Rosa 1994; Lutz 1994a; Preston 1996; O'Neill et al. 1998). Perhaps the most important problem is that there are likely to be important interactions between *P*, *A*, and *T*. For example, higher affluence is likely to be associated with lower pollution per unit of GNP because wealthier societies may invest in technology that minimizes pollution (Preston 1996). Other problems include (1) the upward bias in decompositions at the global level produced by ignoring heterogeneity in each component among regions (e.g., northern countries have the lowest population growth rates but the highest growth rates of carbon production), and (2) the model takes no account of reabsorption or breakdown of gas in the atmosphere (Deitz and Rosa 1994; Lutz 1994a; O'Neill et al. 1998; Preston 1996). Keyfitz (1992) also argued that looking at growth rates in emissions and in *P*, *A*, and *T* is misleading because it is total emissions, not the growth of emissions per se, that affects the atmospheric concentrations of gases.

The conclusions drawn from IPAT decompositions also depend heavily on the periods examined and the assumptions made. Recently O'Neill et al. (1998) examined global changes over the next 50 years. They concluded that, in the short run, income and technology change will have a greater impact on greenhouse gas emissions than will population growth. In the long run, however, the contribution of population growth will increase.

Although the IPAT framework can be a useful thought experiment and illustration of policy options, like all deterministic models it *assumes* rather than *tests* relations between input and output variables. To make progress in understanding the determinants of pollution, demographers have to move to analyses that test hypotheses using variation across locations and/or over time. Preston (1996) took an important initial step in this direction by using a reformulated IPAT model to examine the relationships among regional *variances* in each IPAT term.

A more direct approach, however, is to estimate a behavioral model designed to test hypotheses. For example, using county-level data, Cramer (1998a) estimated a multivariate model of the determinants of air pollution emissions. Although his model is fairly simple, his analytic strategy could be extended to incorporate more variables and to test more complex hypotheses (see, for example, Lutzenhiser and Hackett 1993). Cramer's finding that population growth is more closely linked with some types of air pollution than others (see also Cramer 1998b) provides both useful information for policymakers and intriguing questions for future research. The study also highlights several common problems for analyses of socioeconomic and demographic determinants of pollution, including (1) the heavy data needs, (2) that pollution levels may be tied more to general market demand for products than to demand from local residents, and (3) the potential problems created by air and water spillovers across geographic boundaries.

Land Use and Deforestation

Population pressure on farmland has long been a concern in the demographic literature. A more recent interest is tropical deforestation. In the past, research on population growth and land use was hindered by lack of adequate data (Bilsborrow and DeLargy 1991; Bilsborrow and Stupp 1997). As a consequence, most studies have been either simple descriptive analyses using census data or small case studies whose findings are difficult to compare because of differences in methods, variables, and study areas. Palloni's (1994) extensive review and meta-analysis of this literature highlights its limitations. He concluded, based on current evidence, that "while population pressure is an important force leading to deforestation, it rarely acts alone to produce this outcome" (Palloni 1994:160).

Several recent studies by demographers are an important break from past research (Foster, Rosenzweig, and Behrman 1997; Rindfuss, Walsh, and Entwisle 1996; Rosero-Bixby and Palloni 1996; Shivakoti et al. 1997). Their innovations include analyzing of panel data for large samples of local areas (such as, villages, neighborhoods, or land parcels), combining land-use data from satellite images and/or other sources with socioeconomic and demographic survey or census data, and examining the role of other social and economic changes that may cause or mitigate land-use change. For example, Foster et al. (1997) concluded that, in Indian villages, technological change in agriculture "reinforces the destructive effects of population growth on forests" (p. 33). But they also found that rural industrialization appears to preserve forest land.

Environmental Hazards and Migration

Research on the distribution of environmental hazards and migration has generally focused on industrialized countries (Anderton et al. 1994; Hunter 1998; White and Hunter 1998), although environmental hazards are a serious problem in poor countries as well. These studies, based on local-level data from censuses and other sources, have examined whether hazardous waste sites are more likely to be located in poor and minority communities, and what role environmental hazards play in migration. Some of their results are surprising. For example, Anderton et al. (1994) showed that hazardous-waste sites in the United States are not more likely to be located in poor and/or minority communities (Anderton et al. 1994): They found "no nationally consistent and statistically significant difference between the racial or ethnic composition of tracts which contain commercial TSDFs [hazardous-waste sites] and those which do not" (p. 229). Hunter and White (Hunter 1998; White and Hunter 1998) showed that the presence of environmental hazards lessens the likelihood that migrants will move into a county, but does not affect overall out-migration rates. Certain types of hazards, however, are associated with higher out-migration rates for whites than for minorities.

This overview indicates that several demographers have recently undertaken studies of environmental issues that are outside the traditional demographic interest in natural resources. These studies provide an important base for future population-environment research.

OTHER DEMOGRAPHIC-ENVIRONMENTAL INTERACTIONS

With some exceptions, recent research has continued to focus on the consequences of population growth, especially growth due to natural increase. But population growth is only one of several demographic processes that may affect, or be affected by, the environment. To illustrate this point, I turn to three examples of other population-environment topics that merit demographers' attention and that are closely related to core demographic interests: (1) environmental effects of spatial distribution, (2) demographic determinants of consumption patterns, and (3) the health and mortality effect of environmental hazards.

Spatial Distribution

Spatial distribution, which includes migration, refugee movements, and urbanization, is the result of both migration patterns and regional variations in rates of natural increase. As fertility rates decline, however, migration becomes an increasingly important determinant of spatial distribution.

Many aspects of spatial distribution may affect environmental outcomes:[8] settlement in environmentally sensitive areas such as coastal zones, watershed areas, deserts, and wetlands; the pace of change in spatial distribution; and the specific causes of change in spatial distribution—for example, forced versus voluntary migration (Arizpe and Velazquez 1994; Hugo 1996; O'Lear 1997; Roberts 1994). The effects of spatial distribution on the environment can be complex. For example, is population concentration in a few mega-cities better or worse for the environment than dispersion in many smaller cities and towns? The answer may depend on which environmental outcome is considered. To illustrate, I contrast the potential effects of concentration or dispersion on air and water pollution and on the preservation of wilderness areas and species.

In the case of air and water pollution, concentration in urban areas has both costs and advantages. By concentrating household and industrial by-products in a limited geographic region, mega-cities may overwhelm the local environment's natural absorptive capacity. But concentration also reduces the costs of remediation and regulation. For example, in the last several decades, Los Angeles County has experienced both substantial population growth and improving air quality (CARB 1997). The net effects of urban concentration depend on the efficacy of political and social institutions in regulating and remediating pollution, as well as on the pace of urban growth with which these institutions must contend.

8. As Cohen (1998) suggested, environmental changes, such as global warming, may also be the *cause* of significant changes in spatial distribution in the future.

In the case of wilderness areas and species diversity, population concentration in urban areas may have significant advantages on the whole (although clearly not for wilderness and species located in the path of urban growth). Forest-ecology theory suggests that dispersed settlements can be far more harmful than fewer concentrated settlements. For example, scattered settlements strung along roads (shown as shaded areas in Figure 1) can create islands of forest land or jagged borders between forest and cleared land. Islands or jagged borders can be far more destructive to wilderness than a small number of concentrated settlements that leave large, contiguous tracts of land unsettled (McCarther and Wilson 1967; National Academy of Sciences 1986b; Wilcove, McLellan, and Dobson 1986). Thus, holding constant population size, dispersed settlement patterns may be more harmful to wildlife and wilderness, on the whole, than urban concentration.

Current research on spatial distribution could be readily extended to answer important environmental questions such as, what factors attract potential migrants to, or divert migrants from, sensitive areas such as rain forests and coastal wetlands? How do immigrants decide where to settle in destination countries? What are the environmental consequences of remittances in sending countries? What types of policies can mitigate problems caused by urbanization or dispersed settlement patterns?

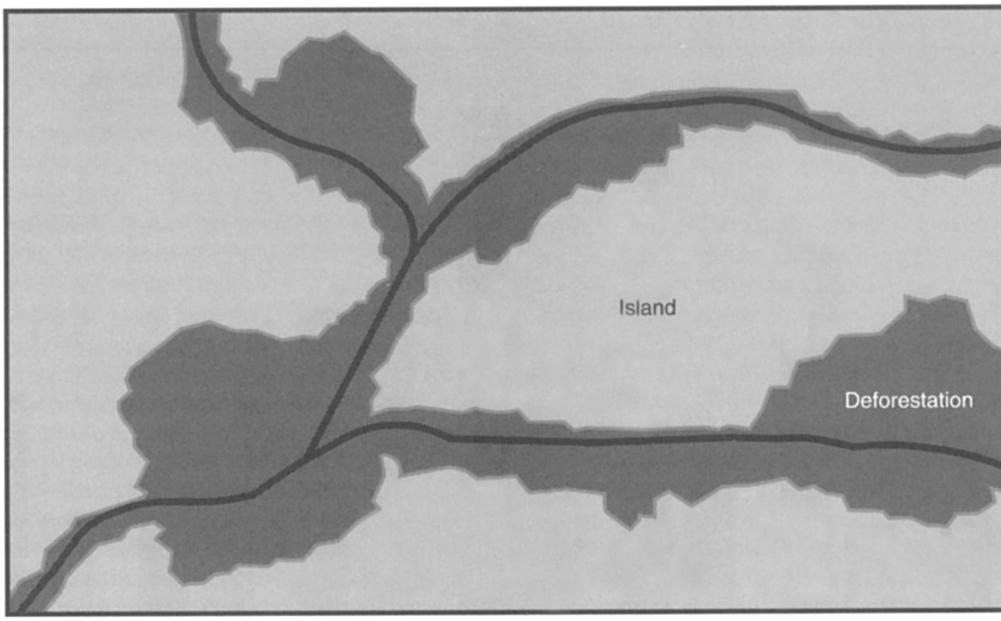
One important caveat in research on the environmental consequences of spatial distribution is that many environmental problems are not directly attributable to the local demographic change (Heilig 1994). Because of the extensive penetration of markets into virtually all areas of the world, local environmental degradation may be caused by demand for local products from other parts of the country or the world. For example, small farmers in eastern Guatemala export fertilizer- and pesticide-intensive peppers to Saudi Arabia. The environmental costs are incurred in rural Guatemala, but the consumption occurs in Saudi Arabia. Similarly, although the demand for paper products in the United States comes from a national market, the pollution costs of manufacture are borne by particular local areas. Future research on population distribution and the environment must consider that demand for local goods and services is often driven not by local population change but by national and international markets.

Changing Consumption Patterns

Consumption may negatively affect the environment through harmful by-products generated during production or consumption and through disposal of goods once consumption is complete. For example, a car's production requires raw materials and generates waste products. Cars run on fossil fuels, producing carbon. Their operation also generates other waste products, such as used oils, fluids, and tires. And the car must be disposed of when its useful life is over.

Per capita consumption of all goods, and especially higher value-added goods, is likely to increase in the next several decades because of rising living standards, especially in poor countries. Several demographic factors will also af-

FIGURE 1. ISLANDS OF FOREST



fect consumption levels and patterns, including (1) population aging, (2) household-formation patterns, and (3) social inequality. Let me briefly comment on each factor.

Current population projections suggest that most countries in the world will experience population aging over the next 50 years (Heilig 1996; Kinsella and Taeuber 1993). Population aging may affect consumption patterns substantially.[9] Consider, for example, results from the U.S. Consumer Expenditure Survey shown in Figure 2. Expenditures on utilities, transportation, and housing have a distinct age pattern, with lower consumption at younger and older ages and higher consumption in the middle ages. In 1995, the median age of householders was in the 45–54 age group (U.S. Bureau of the Census 1996). As Figure 2 shows, this is the age group in which household expenditures on housing, utilities, and transportation are highest. If the age patterns of consumption shown in Figure 2 persist over time, expenditures are likely to decrease in the future as householders become older. Current age patterns for older adults, however, reflect lower lifetime incomes for older cohorts and cohort consumption patterns developed in leaner economic times. Age patterns of consumption may change substantially in the future as baby-boomers move into their early retirement years. Understanding the implications of aging for consumption and the environment will require research on life-cycle patterns of consumption, which takes cohort effects into account.

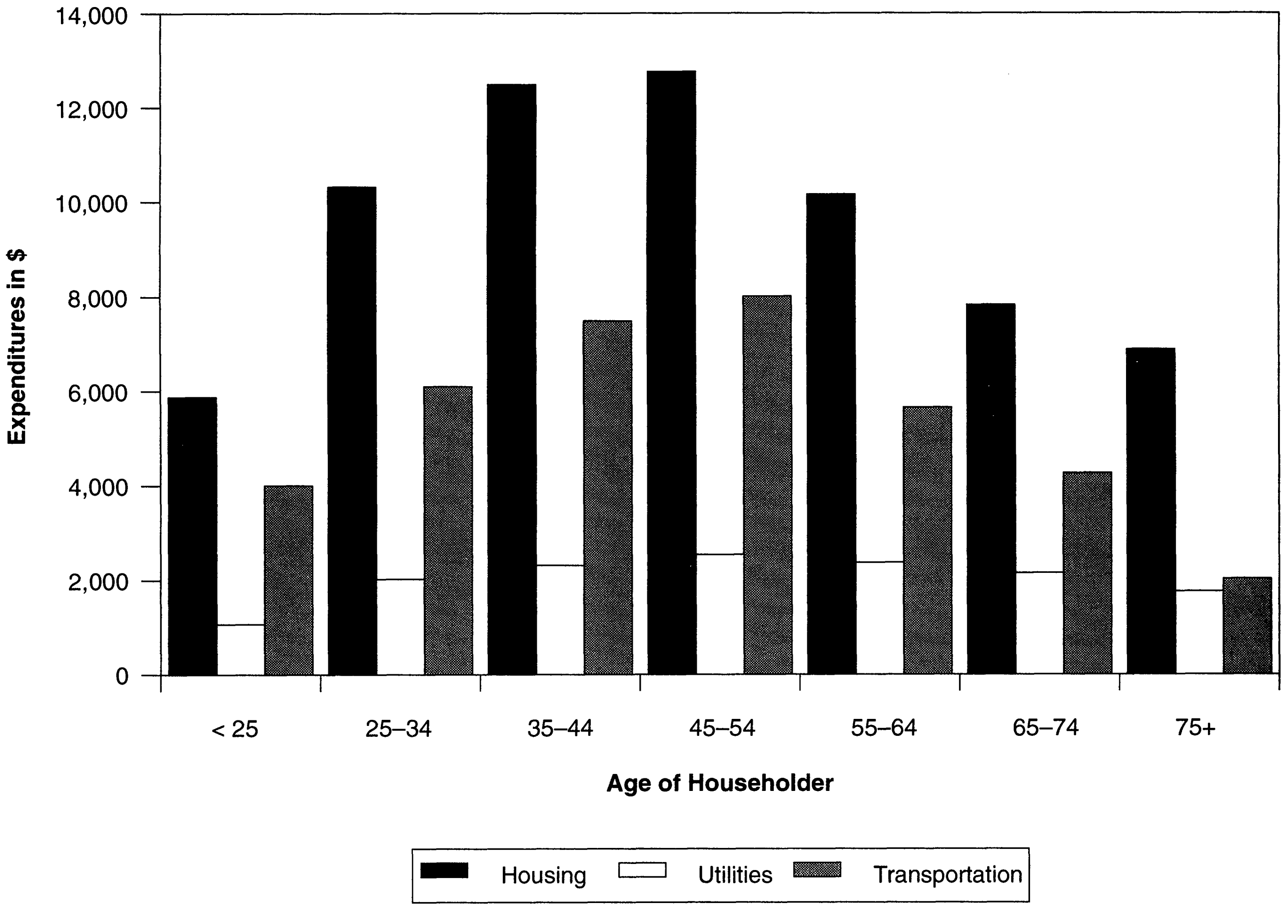
Household formation also affects consumption patterns. As Figure 3 shows, average household size has been declining and is projected to decline further. In other words, the number of households is likely to grow faster than the population itself. Because there are substantial fixed energy, waste disposal, and other costs to running a household, the growth in the number of households implies growth in consumption. For example, MacKellar et al. (1995) showed that growth in greenhouse gas production is more closely linked to growth in the number of households than to population growth per se.

Aggregate consumption is also affected by social inequality. The effects can be complex. For example, Table 2 shows that households with the highest income in the western United States used twice as much gasoline as the poorest households (Lutzenhiser and Hackett 1993). But they also used energy more efficiently: Because higher income households are more likely to have newer cars, they got considerably more miles to the gallon. In general, the poor have fewer resources to invest in newer, more efficient technology (for example, newer, more fuel-efficient cars in the United States or high-efficiency wood-burning stoves in rural areas of poor countries). At the extreme, a high degree of social inequality may result in both heavy total consumption by a small and wealthy elite and very inefficient consumption by the majority of the population.

The effects of consumption on the environment is a hot topic in current environmental debates (Myers, Vincent, and Panayotou 1997; Royal Society and U.S. National Academy of Sciences 1997; Stern et al. 1997). Yet much of the discussion is simplistic and lacks a solid empirical base. Demographers could make important contributions by extending current re-

9. There is a growing literature on the effects of aging on savings, standards of living, and consumption patterns. See, for example, Hurd (1997), Lee and Tuljapurkar (1997), and Wise (1997). For other approaches to consumption, see Stern et al. (1997).

FIGURE 2. U.S. EXPENDITURES ON HOUSING, UTILITIES, AND TRANSPORTATION FROM THE 1995 CONSUMER EXPENDITURE SURVEY



Source: U.S. Bureau of Labor Statistics (1998).

search on aging, household formation, and social inequality to examine their effects on consumption and the environment.

Environmental Change and Health

The previous two topics concerned the effects of demographic variables on environmental outcomes. But environmental change may also have important effects on *demographic* outcomes, including health, mortality, and migration. I illustrate with the example of health and mortality effects.

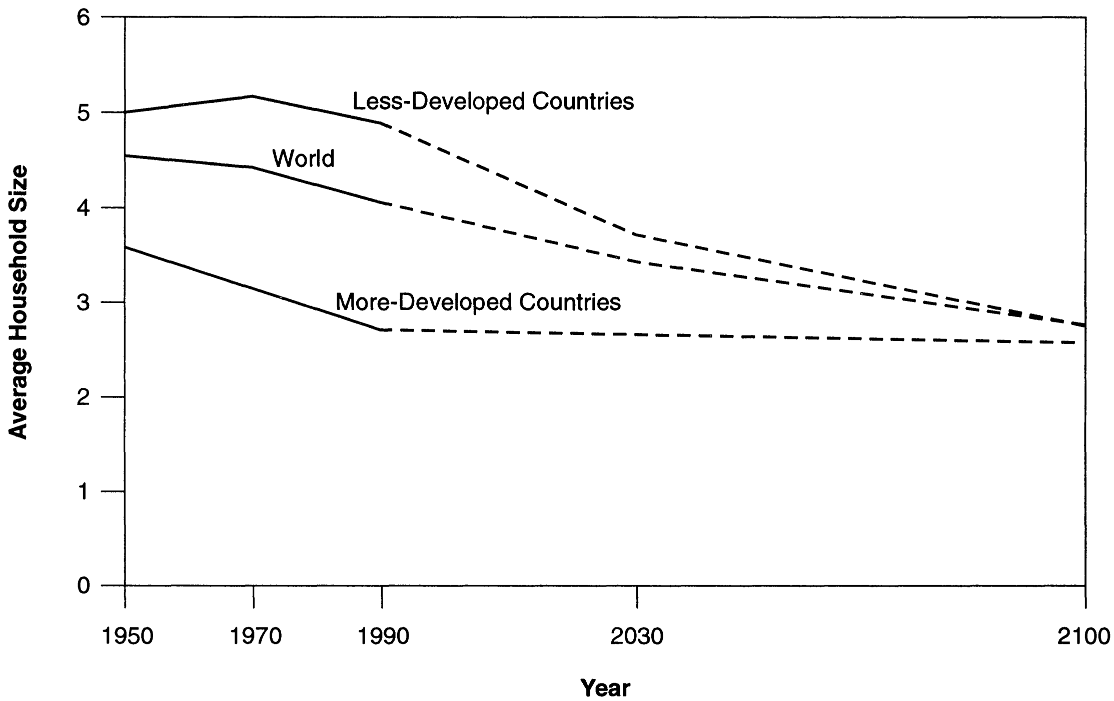
Environmental factors are likely to play a small but significant role in mortality and morbidity over the next several decades. For example, Murray and Lopez (1996) estimated that air pollution accounts for about 1% of annual deaths worldwide (but see Schwartz 1993 and Shprentz 1996). But environmental factors can be more important in specific locations (such as eastern Europe and coal-dependent industrial towns in China) and for particular social groups (such as the urban poor). As worldwide mortality declines, health catastrophes may also play a more significant role in period mortality. For example, the recent massive forest fires in Indonesia may have increased morbidity and mortality in Malaysia, Singapore, and Indonesia. As I argued earlier, environmental changes can also indirectly affect human health by altering the ecology of microorganisms that cause disease in humans (Olshansky et al. 1997).

Future demographic research on mortality and health must take environmental factors into account. For example, for studies of trends and differentials, important issues include the effects of environmental change on mortality rates; the role of social and economic factors in environment-health relationships; and the role of policies and individual preventive behavior in reducing environmental health risks.

WHERE DO WE GO FROM HERE?

Will environmental issues have a more central place in demographic research in the future? My view is that although

FIGURE 3. AVERAGE HOUSEHOLD SIZE, 1950–2030



Source: MacKeller et al. (1995).

they are unlikely to supplant fertility determinants, for example, as a central topic in demography, there are important reasons for demographers to become more involved in research on environmental issues.

Some of the reasons are fairly obvious. Policy debate on the environment will continue and probably increase, with or without the involvement of demographers and other social scientists. Given the importance of environmental problems and the often rudimentary understanding of demographic and social processes in the environmental literature (Ehrlich and Ehrlich 1990; Myers et al. 1997; Royal Society and U.S. National Academy of Sciences 1997; Smail 1997; Stern et al. 1997), demographers can make important contributions to this discussion, and are already doing so to some degree.

Research on environmental issues can also benefit demographic theory and knowledge. For example, demographers have become increasingly interested in the relationship between the social and economic environment and individual behavior. Articles in demographic journals include studies of contextual or ecological variables, such as social ties and social capital, neighborhood or village infrastructure, wages and prices, regulations, and the availability of services (e.g., Brewster 1994; DeGraff, Bilsborrow, and Guilkey, 1997; Entwisle, Rindfuss, and Guilkey 1996a; Lundberg and Plotnick 1995; Pebley, Goldman, and Rodríguez 1996; Sastry 1996). Demographic research on the environment can extend our current focus on the *socioeconomic* context of human behavior to its *physical* context.

Previous research on population and the environment by demographers suggests several research strategies that are and are not likely to extend current knowledge. Most previous research is based on either macrosimulations or projections, or on case studies. Both have limitations. Macrosimulation and projection models depend heavily on assumptions. They are, therefore, most useful as ways to *summarize* empirical knowledge rather than to *generate* it. Case studies of a single village, region, or country can be a useful starting point, but they generally do not provide a solid basis for comparison or inference, given their wide variation in methods and variable measurement, small sample sizes, and selectivity of research sites.

A few recent studies point the way to a more productive approach. All of these studies test hypotheses based on behavioral models, analyze panel or time series data, link survey or census data with environmental data, and measure variables in a standard and replicable manner. Two other important features for future research are the use of common theoretical frameworks to allow comparison of study results and analysis of institutional and policy variables. If institutional and policy variables are as important as we think, understanding their effects should be a central focus of demographic research on the environment.

TABLE 2. HOUSEHOLD CONSUMPTION OF GASOLINE BY INCOME GROUP: WESTERN UNITED STATES, 1987

Annual Income	Average Annual Household Consumption of Gasoline (in Gallons)	Miles per Gallon
< $12,500	541	16.6
$12,500–24,999	766	17.9
$25,000–39,999	1,013	17.3
$40,000+	1,241	19.1

Source: Lutzenhiser and Hackett (1993).

On the whole, demographers are a pragmatic and skeptical group who like empirical evidence and disdain dramatic rhetoric. This attitude may be partly a legacy of Thomas Malthus and the fact that the dire predictions in his first *Essay* have not been borne out. During the 200 years since this *Essay*, many other observers have argued that humans would exhaust natural resources and face environmental collapse. These predictions were especially common in the 1960s and 1970s, when many of us first decided to become demographers. Remarkably, in the 20–30 years since then, we have witnessed increased living standards and survival rates, a fertility decline in most areas of the world, and some success in reducing environmental damage. That these catastrophic predictions were wrong, however, should not blind us to more mundane, but potentially quite important, interactions between demographic and environmental processes.

As Malthus' later work shows, he also had a firm belief in the importance of empirical evidence as a basis for drawing conclusions, and he was willing to alter his beliefs as the evidence required (Coale 1978). That is a part of Malthus' legacy that I think we all can appreciate.

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