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Migration, Population Change, and the Rural Environment

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Migration, Population Change, and the Rural Environment

- Richard E. Bilsborrow, University of North Carolina at Chapel Hill -

Migration, Population Change, and the Rural Environment [1]

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Executive Summary

The movement of human populations across the planet has been a major characteristic of human societies throughout history. Historically this movement has been induced mainly by the scarcity or depletion of resources. In recent years rural populations and their relationships to their environment are again attracting growing interest, especially in connection with migration. This paper considers the linkages between rural populations, migration from and to rural areas, and the environment in developing countries.

To address these issues, we first must understand ongoing demographic processes in developing countries. I therefore review recent evidence (mostly from UN sources) on rural population dynamics—on the size of rural populations, past and expected future growth, and implications for rural population density. The process of urbanization spread to the developing world during the twentieth century. The movement of people from rural to urban areas has led to declining rates of rural population growth in developing countries. Growth rates became negative for most countries in Latin America before the turn of the millennium and will become negative for most countries in Asia and Africa during the first half of the new century. Nevertheless, rural populations will continue to grow for several decades more in most of Sub-Saharan Africa and parts of Asia and Central America, leading to increasing pressures on land and other natural resources. More important, even where rural populations are declining, rural-rural migration will continue to be a demographic phenomenon with major potential implications for the rural environment. Indeed, its importance has been rarely recognized, with research on migration focusing overwhelmingly on rural-urban migration. Nevertheless, rural-rural migration is higher than rural-urban movement in 11 of the 14 developing countries with the necessary data. It is this migration than must be studied much more in assessing population-environment linkages.

Following a section in which I indicate that the main environmental resources I directly address here are agricultural land, forests and drylands, theoretical issues in addressing the linkages between rural populations, migration and the rural environment are discussed. Two bodies of theory are relevant. The first, on population relations with land, provides a framework that helps us understand the relationships between population (and thereby in-migration) on areas that migrants move to. This draws on Malthus, Boserup, Kingsley Davis, and my own work, as well as on political ecology, and postulates relationships between population density and land use, including land clearing or land extensification, land intensification and out-migration. The relationships are hypothesized to vary according to the context, that is, according to initial population density, land tenure and distribution arrangements, transportation networks and other socio-economic infrastructure, local and national agricultural and economic policies, and natural resource endowments. The second relevant area of theory is that on the determinants of migration. This is important given that much of the environmental degradation occurs in areas people are migrating to, such as tropical rainforests, so it is necessary to where they are coming from and why to get at the root causes of that degradation. While economic factors, especially

employment opportunities and wage rates, dominate the motives for migration, environmental deterioration (such as declines in soil fertility from prolonged use) may often be an underlying factor if it contributes to declining agricultural yields and incomes. However, there has been virtually no convincing quantitative research on this topic—one begging for attention.

The largest section of the monograph (section 4) reviews and assesses much of the recent empirical research on the effects of population and (in-) migration on the environment in destination areas, looking at countries in Latin America, Asia and Africa. Studies in each region find substantial linkages between population size/ density or in-migration and environmental degradation, such as deforestation or soil desiccation. In some countries natural population growth has also been a prominent factor, such as in central Africa, Ethiopia, and Central America. In the Ecuadorian Amazon both high fertility and in-migration are contributing to subdivision of plots and a second generation wave of deforestation. In Brazil, poor soils have often led migrant colonists to abandon their initial plots (to cattle ranches) and move further into the rainforest along the expanding road network, extending the agricultural (and deforestation) frontier. In Latin America as a whole, most of the increase in agricultural land eventually ends up as pasture, which is evidently related to growing national and international demands for beef. In Honduras and the Philippines, the expropriation of better agricultural soils in lowland areas for the expansion of commercial agriculture has forced growing rural populations to move up the mountain slopes, deforesting them. In eastern Africa the expropriation of lands for government agricultural schemes (Sudan) or national parks and game reserves and efforts to settle nomadic pastoralist populations has led to increased competition for land, water and fuelwood among growing populations, leading to both desiccation of soils and deforestation. In Nepal the elimination of malaria led to migration to the Terai foothill region of the Himalayas and deforestation, adding to downstream flooding in Bangladesh. In all of the above situations pull factors facilitate or even encourage the population movements that expand the agricultural frontier at considerable ecological expense, such as the building of roads by lumber companies or mining operators. While the activities of the latter often in turn follow from misconstrued government policies as well as the demands of foreign markets, population factors are generally important contributory causes as well of the ecological damage at the agricultural frontier.

Regarding policy implications, an important caveat arises from the fact that much of the empirical research has sufficiently serious shortcomings that one should be wary of accepting the results as valid enough to draw policy recommendations. That said, in most destination areas, at the agricultural frontier, a number of policies appear to usually be desirable to attempt to reduce the pressures of populations on resources while at the same time assisting existing settlers (most of whom are poor) to improve their living standards. These include:

- Provide more technical assistance, to encourage intensification of crop growing crops of higher value, and therefore higher productivity of land use in crops.
- Reorient credit exclusively for crops and agro-forestry rather than cattle.
- Promote agro-forestry as a sustainable approach to land use.

- Establish a sustainable program of payments to farmers for preserving significant patches of forests, as a payment for environmental services.
- Improve land titling.
- Work with local town governments to develop small industries to add value to local agricultural commodities, to promote off-farm employment opportunities.
- Work with farmers groups to establish direct control of commercialization.
- Create protected areas where sufficiently large patches of forests or drylands with high or unique biodiversity still exist.
- Improve access to education to make non-agricultural employment a more feasible option for children of migrant settlers.
- Increase the provision of health and family planning, to facilitate women having the (smaller) numbers of children they desire to have, and to reduce second generation impacts on land and other resources at the frontier.

But such policies only address the *proximate* causes of land use degradation. To address the root causes, one needs to know where the migrants are coming from and why. Though this has not been specifically addressed in quantitative research studies to date, from other studies on the determinants of out-migration from rural areas we know that it is usually due to the lack of land or of a secure title to one s plot, poor quality land or lack of water, lack of off-farm employment opportunities, and lack of local infrastructure important for the quality of life (e.g., schools, health facilities, transportation and communications linkages). The lack of land is usually due to population pressure and past growth and subdivision of plots among children as well as to agrarian regimes characterized by highly concentrated landholdings. National policies should change to adopt some form of land redistribution as well as reduce the urban bias in development policies prevailing in developing countries.

In the final section on shortcomings in research and future needs, I note the lack of adequate and representative data sets (especially on households/farms and the context within which they make decisions, such as communities), of quantitative modeling that separates out the effects of demographic vs. other variables on land use and land cover change, and the virtually complete lack of research on origin areas. Thus I close with a plea for more attention to the *root causes* of the migration flows to ecologically important areas, and therefore to studies of the determinants of out-migration from areas of origin.

Introduction

The movement of human populations across the planet has been a major characteristic of human societies throughout history. Historically this movement has been induced mainly by the scarcity or depletion of resources, which has led people to move elsewhere seeking resources to sustain themselves[2]. In recent years, rural populations and their relationships to their environment are again attracting growing interest, especially in connection with population change, notably migration. It is in rural areas where most of the forested land (tropical rainforests, sub-tropical forests and temperate forests) and other lands such as agricultural lands, semi-arid lands and drylands exist, and where humankind obtains most of its food and sustenance. Most of the world s gene pool is also found in rural environments: While tropical rainforests and coral reefs have attracted the most attention since they have the highest densities and diversities of species per unit area, other biota such as highland forests, wetlands, savanna, and drylands and deserts all also contain unique floral and faunal diversity. All of these biota are threatened to varying degrees by the growth and intrusions of human populations.

This paper considers issues pertaining to the linkages between rural populations, migration from and to rural areas, and the environment, focusing on developing countries in the latter part of the twentieth century. I concentrate also on internal migration, though some comments on the state of knowledge concerning international migration and the environment are proffered as well. Questions to be addressed include: What are the recent-- and expected future-- patterns of rural population growth? Among the different types of internal migration in developing nations, how much is directed towards rural environments? What kinds of rural environments are people moving into, in what countries, and what are the environmental consequences? Are there relationships in the other direction as well, that is, is environmental deterioration an important factor in *out-migration* from rural areas? Are there environmental effects in rural places of origin when people move away from those areas?

The paper is organized as follows. First, the basic demographic facts are reviewed on the size of contemporary rural populations, their density and recent past and expected future trends in growth, based on the latest United Nations estimates and projections. Major differences are noted between the developed and the developing countries and among regions within the developing world. Patterns of population redistribution through migration are then considered, noting the importance of rural-rural migration. Section 2 considers several forms of environmental degradation that may be affected by migration to/from rural areas and their relationship to rural poverty. Section 3 briefly reviews relevant theoretical approaches, especially pertaining to the determinants of migration and the analysis of its environmental consequences. The next section assesses empirical evidence on the environmental consequences

[2]A striking pictoral-textual view of human migration processes in history is presented by Davis in a 1972 issue of Scientific American, subsequently reprinted (Davis, 1974).

of migration into rural areas, and is the largest section of this paper since that is where research has tended to focus. The effects are examined for developing countries grouped by region. This is followed by a short discussion of the environmental consequences of out-migration on areas of origin. Section 5 then looks at the other side of the coin, the effects of environmental degradation on stimulating or forcing migration, both national and international. Section 6 provides a short summary and preliminary policy implications, while the final section considers gaps in knowledge and therefore key areas for research on the linkages between migration and the rural environment.

1. Rural populations in the developing world: size, density, growth rates and patterns of redistribution through migration

Table 1. Rural Population Sizes, Rates of Growth and Rural Density, 1960 to 2030

Major area	*Percentage of the population in rural areas*			*Rural population (millions)*			*Rate of growth of the rural population (percentage)*		*Land in arable and permanent crops (1,000,000 ha.)*		*Persons per hectare of arable and permanently cropped land*		
	1960	*2000*	*2030*	*1960*	*2000*	*2030*	*1960-2000*	*2000-2030*	*1961*	*1998*	*1961*	*1998*	
World	66.4	53.0	39.7	2 005	3 210	3 223	1.18	0.01	1,346	1,512	1.51	2.10	1.122986
Less developed regions	78.4	60.1	43.8	1 652	2 925	3 023	1.43	0.11	676	855	2.49	3.37	1.265149
More developed regions	38.6	24.0	16.5	353	285	200	-0.54	-1.19	670	656	0.52	0.44	0.979509
Africa	81.5	62.1	45.5	225	487	640	1.93	0.91	155	202	1.48	2.34	1.303424
Asia	79.2	63.3	46.6	1 348	2 331	2 272	1.37	-0.09	484	556	2.84	4.13	1.149799
Europe	42.0	25.2	17.4	254	184	120	-0.81	-1.42	345	311	0.73	0.60	0.901718
Latin America and the Caribbean	50.7	24.7	16.8	111	128	122	0.37	-0.18	102	159	1.09	0.80	1.556167
Northern America	30.1	22.8	15.6	61	71	58	0.35	-0.65	226	225	0.27	0.31	0.99553
Oceania	33.6	29.8	25.6	5	9	11	1.35	0.51	35	59	0.15	0.15	1.688439

Sources: Population Division of the Department of Economic and Social Affairs of the United Nations, World Urbanization Prospects: The 1999 Revision, Data Tables and Highlights (ESA/P/WP.161), March 2000; Food and Agriculture Organization, Statistical Databases: Land Use, http://apps.fao.org/lim500/nph-wrap.pl?LandUse&Domain=LUI&servlet=1, July 2000.

Before the linkages between the environment and demographic processes in rural areas can be considered, the key facts pertaining to rural populations must be known. The past century or so has witnessed a profound shift in the world s population distribution from being primarily rural to increasingly urban. As a result of this historical process, at the turn of the new millennium only a quarter of the population of the developed world and of Latin America lives in rural areas; nevertheless, despite similar ongoing trends in population redistribution, in both Asia and Africa—home to three quarters of the world s population--nearly 2/3 of the populations still live in rural places (Table 1). The pace of rural population decline, moreover, appears to be slowing in many places in recent decades as rural areas have become depleted and cities increasingly crowded. Still, the many advantages of urban areas--including greater human interaction, the store and accumulation of knowledge and culture, and modern services, infrastructure, media and diversions often facilitated by economies of scale in production or distribution--are such that the proportions living in urban areas are expected to continue to grow in the future. Indeed, over the next 30 years the urban population of the world is anticipated to grow by the same amount (2 billion) as the world total, so there will be no net overall rural population growth. During this

time, the percentage living in rural areas in developed countries is expected (according to medium UN population projections--see UN 1999) to continue to fall, from 24 in 2000 to 16 by 2030,[3] while the fall in the developing regions is expected to be more rapid, from 78 in 1960 to its current overall level of 60 in the year 2000 and to 44 by 2030.

The percentage rural and its evolution over time varies widely by region in the developing world, being as low as 25 already in Latin America in the year 2000, compared to 63 and 62 in Asia and Africa. These percentages are expected to fall to 17, 47 and 46, respectively, by 2030. For the world as a whole, including both developed and developing countries, the median rate of rural population growth was 1.2 percent in 1950-75, 0.6 percent in 1975-2000, and (projected) —0.1 percent in 2000-2030. Thus rates of rural population growth are projected to decline in all regions of the world in the period 2000-2030 compared to the period 1960-2000. However, these rates will continue to be positive in many sub-regions, and will be significant (around one percent or more per year) in much of Africa and Micronesia-Melanesia.

[3] The latest UN projections prepared in 2000 are based upon trends in fertility and mortality (and international migration), which should never be considered forecasts, but rather contingent on a continuation of recent past trends, combined with assumptions about future paths of fertility and mortality, the most important one being the level of fertility at the end of the projection period and the pace of decline towards that level for each country.

Table 2. Population Sizes and Growth Rates of the Developing Countries with the Largest Rural Population, 1960-2030

Country	*Rural population (millions)*			*Rural growth rate (percentage)*	
	1960	*2000*	*2030*	*1960-2000*	*2000-2030*
China	552.2	867.6	743.9	1.13	-0.51
India	362.9	725.4	749.3	1.73	0.11
Indonesia	82.2	125.3	103.6	1.05	-0.63
Pakistan	38.9	98.5	123.7	2.32	0.76
Bangladesh	48.8	97.5	105.2	1.73	0.25
Vietnam	29.6	64.1	74.9	1.93	0.52
Nigeria	32.3	62.5	72.0	1.65	0.47
Ethiopia	21.3	51.5	82.7	2.21	1.58
Thailand	23.1	48.1	45.1	1.84	-0.22
Egypt	17.3	37.5	40.3	1.94	0.24
Democratic Rep. of the Congo	11.9	36.0	59.8	2.77	1.69
Myanmar	17.6	33.0	32.0	1.58	-0.10
Brazil	40.1	31.8	25.0	-0.57	-0.80
Philippines	19.2	31.4	29.9	1.23	-0.17
Iran	14.2	26.0	25.2	1.51	-0.11
Mexico	18.2	25.3	24.4	0.83	-0.12
Tanzania	9.7	22.5	28.2	2.10	0.75
Nepal	9.0	21.1	29.7	2.14	1.14
Kenya	7.7	20.1	20.2	2.40	0.02
South Africa	9.3	20.0	17.0	1.92	-0.55
Sudan	10.0	18.8	20.7	1.58	0.32
Uganda	6.2	18.7	34.7	2.75	2.06
Afghanistan	9.9	17.7	29.4	1.46	1.69
Turkey	19.3	16.4	11.6	-0.41	-1.16
Uzbekistan	5.7	15.4	18.5	2.50	0.62
Sri Lanka	8.1	14.4	14.1	1.43	-0.08
Yemen	4.8	13.6	25.8	2.63	2.12

Source: United Nations (1999).

Table 2 shows the largest developing countries in the world in terms of rural population size at the turn of the millennium. Three countries currently have over 100 million people living in rural areas--China, India and Indonesia. Two more Asian countries will join that list by 2030. Of the 27 countries in the table, 16 will continue to experience positive rural population growth over the next three decades. Of the eight countries with the largest rural populations in 2000—each with over 50 million--all but China and Indonesia will experience overall rural population growth in the coming decades. India will surpass China in having the largest rural population shortly before 2030. Looking at the developing countries with the largest *total* populations by continent, the current (year 2000) percentages of the population living in rural areas in the Asian countries of China and India, the African countries of Nigeria and Ethiopia, and the Latin American countries of Brazil and Mexico are 68 and 72, 56 and 82, and 19 and 26, respectively. These figures are projected to fall to 50 and 54, 36 and 65, and 11 and 18, respectively, by 2030 (UN, 2000).

If we look at the projections for individual countries, annual rates of rural population growth in the next three decades are expected to be highest, exceeding 2 percent, in Yemen and Uganda, followed by over 1.5 percent in Somalia, Burkina Faso, the Congo, Afghanistan, Liberia, Ethiopia

and Burundi. Countries experiencing such large increases in their rural populations will confront growing pressures on resources and may well experience further environmental degradation in rural areas. This includes Ethiopia, the Congo, Nigeria, Pakistan, Vietnam, Bangladesh and India.

At a regional level, the highest rates of rural population growth are expected to be in central Africa, which contains countries and sub-regions characterized by not only high population density but also civil conflict. Table 1 shows land in arable and permanent crops in 1961 and 1998 and rural population density measured as rural population divided by agricultural land. As rural populations have grown, they have expanded their agricultural area--called agricultural extensification --as indicated by the increase in the agricultural land area (except for a decrease in Europe and constant land area in North America). The land area increased by 26 percent overall in the developing world during the 37 year period, but this varied dramatically across regions, being 56 percent in Latin America, 30 percent in Africa and 15 percent in Asia. Most of the expansion in agricultural production in Latin America during the period came from a vast expansion of the agricultural frontier, but the latter accounted for only a small part of the large increase in agricultural output in Asia, where increasing productivity per unit of land was the main factor. In Africa, food production per person failed to rise during the period, and the agricultural frontier advanced, but there was much less potentially usable agricultural land available for people to migrate to in Africa than in Latin America. It is the *combination* of the expansion in the land area and rural population growth that is reflected in the last two columns of the table. For the developing world as a whole, rural population growth was considerably higher than the increase in agricultural land, with the result that total population per hectare rose from 2.5 to 3.4 or by 35 percent. The biggest increase was in Asia, from 2.8 to 4.1, but it also rose from 1.5 to 2.3 in Africa, where productivity gains were minimal (Cleaver and Schreiber, 1994; FAO, 1996). In Latin America, in contrast, the rural population hardly grew, with the result that rural population density actually declined significantly overall.

Most countries of eastern Africa are expected to have substantial rural population growth--a discouraging prospect given the lack of productivity increases in agriculture, the lack of unused lands to exploit (semi-arid areas with little agricultural potential), and the large areas already degraded. Both South Asia and western Asia will experience modest future rural population growth, and already have very high rural population densities relative to arable land. In the Western Hemisphere, the one region expected to experience rural population growth is Central America, where most countries are already densely populated, have degraded rural environments (Leonard, 1987), and are not expanding agricultural output sufficiently to achieve much economic growth. Fertility and overall (natural) population growth also continue to be much higher than elsewhere in Latin America.

The population figures and projections introduced above show the rural populations of many countries declining already before 2000, with more countries joining this list by 2030 (population sizes peaking in all but a few dozen countries in Africa and Asia). Therefore, the question arises

as to how a *declining rural population* can affect the rural environment, since overall population pressures on the land will not be rising and will be increasingly falling. The answer is through *rural-rural migration*, that is, migration from one rural area to another, accelerating the decline in rural density in one area but raising it in others. As we will see below, this has occurred, and will continue to occur, as rural populations leave areas where they have little land to seek land (or more or better land) elsewhere. Throughout the past century, and right up to the present, demographers and other social scientists interested in migration have focused on *rural-urban migration*--doubtless due to the rapid growth of cities and the important roles they have played in the progress of civilization and economic development. But that preoccupation is also due to the prevailing urban bias of development policy (Lipton, 1977), of modern education systems, and of the researchers themselves-- virtually all raised and trained in urban environments. From the literature, one would think that other forms of population movement hardly exist. But in fact they have usually been and even now continue to be *more important than rural-urban* movements. The importance of the different types of flows varies over time in countries as they evolve from being primarily rural, as all once were, to primarily urban, as all will be at some time in the new century. Table 3 provides data (mostly pertaining to the 1980s) on the four mathematically possible directions of internal migration flows within developing countries, based on available data. Evidently, the sample of countries is a convenience sample (or inconvenience sample, due to its limitations), and is not representative of the regions. The data also suffer from wide differences in the definitions of urban used by countries, rendering comparisons across countries hazardous.

Table 3. Migrants by Type of Flow, According to Urban or Rural Origin and Destination

Country	*Census year*	*Type of data*	*Percentage*			
			Rural-urban	*Urban-urban*	*Rural-rural*	*Urban-rural*
A. Africa						
Botswana	1988	Place of birth	60.0	8.0	29.0	3.0
Cote d'Ivoire	1986	Previous residence	14.8	44.2	20.3	20.7
Egypt	1976	Inter-state	26.0	55.2	12.0	6.8
Ghana	1988	Previous residence	4.6	48.5	9.5	37.3
B. Asia						
India	1971	Place of birth	14.6	10.4	69.1	5.9
India	1981	Place of birth	16.7	11.9	65.4	6.1
Malaysia	1970	Residence in 1965	8.8	20.0	38.8	32.4
Pakistan	1973	Residence in 1965	17.3	38.8	32.6	11.4
Philippines	1973	Residence in 1965	39.3	25.2	19.7	15.8
Republic of Korea	1966	Residence in 1961	36.6	32.0	21.2	10.2
Republic of Korea	1975	Residence in 1970	43.5	28.7	14.0	13.8
Republic of Korea	1995	Residence in 1990	12.8	85.7	1.5	7.0
Thailand	1980	Residence in 1975	15.4	18.5	56.0	10.2
C. Latin America						
Brazil	1970	Place of birth	17.4	50.4	26.5	5.6
Ecuador	1982	Residence in 1977	16.0	46.0	18.0	21.0
Honduras	1983	Residence in 1978	26.0	32.0	28.2	13.9
Peru	1986	Previous residence	11.6	51.6	13.6	23.2

Sources: See UN (1999), except for Botswana, Cote d'Ivoire, Ghana, Ecuador, and Peru, see original sources in Bilsborrow (1992), based on population census data (except for Peru, based on the Living Standards Measurement Survey supported by the World Bank).

If we eschew these caveats, it is striking that rural-urban migration is the most important for *only two* countries in the list, while urban-urban migration is most important for nine and rural-rural for three. Surprisingly, rural-rural migration is larger than rural-urban in 11 of the 14 countries, including the largest three, India, Pakistan and Brazil.[4] This suggests that substantial changes in population distribution have occurred and are continuing to occur in rural areas of developing countries, in addition to those from rural to urban areas. These changes are linked to powerful forces of attraction and (sometimes also) repulsion resulting from wide differences in living conditions and economic opportunities between areas and across regions. The extent to which environmental factors are important in inducing these flows, and the extent to which there may be important environmental consequences, are the main topics of this monograph, and are covered in later sections below.

[4]Trends over time are available in the data only for Korea and India. The former underwent a striking transformation from a low income economy to a middle income economy in the period (1966-95), which was linked to its population redistribution: While prior to 1966, rural-urban, urban-urban and rural-rural migration movements were all significant, by the 1990s most of the population was living in cities, so urban-urban migration was dominant.

2. Environment indicators and the poor

Before we can consider potential linkages between migration and the environment, we need to have a clear understanding of what we mean by both terms. First, it is important to identify the main measures of *rural* environmental degradation to be considered: These are deforestation, declining soil quality (including soil desiccation), and loss of biodiversity [5] We deal with these three in order, beginning with deforestation. Other forms of environmental degradation, such as water contamination and shortages (including mining of underground aquifers, which is widespread), air pollution, toxic and nuclear emissions into air, water (e.g., mining wastes into rivers) and soil, and salinization from continual irrigation with insufficient flushing of salt buildups from evaporation) are not considered, either because they are more problems of developed countries and/or urban areas, or because they have received little attention in the context of population-rural environment linkages.

The latest FAO data (FAO, 2001) indicate that half of the forests that still existed in developing countries in1950 were lost by 2000. Furthermore, the pace of deforestation accelerated in the 1990s compared to the 1980s. The *annual stock* of forests lost was highest in Latin America in the 1990s (at 4.8 million ha/year compared to 3.7 and 2.9 for Africa and Asia), but the *annual rate* of loss of forests was often largest in countries which had already experienced much deforestation in earlier years (or centuries, as in much of Asia), where so little of the original forests remained due to centuries of dense habitation and exploitation for human use. Thus the annual rates of deforestation in the 1980s were highest in Thailand and Costa Rica, at about 7 percent, with both countries losing about half their extant stock of forests in a single decade. At the same time, the overall volume of forests lost was by far the greatest in Brazil, followed by Indonesia and India. In the latest period of 1995-2000, the annual loss of forests was greatest by far again in Brazil (2.2 million ha/year), followed by Indonesia (1.3 mh/yr), Sudan, Zambia, Mexico, Congo and Myanmar (all 0.5 to 1.0 mh/yr). But annual *rates* of deforestation were highest (among countries with stocks of at least 10 million ha of forests in 1995) in Nigeria (2.6 %/year), Zambia, Zimbabwe, and the Sudan, in Africa; in Myanmar (1.4 %), Malaysia and Indonesia, in Asia; and in Ecuador and Mexico, in Latin America (1.2 %). A few countries with small extant stocks had disastrous rates of 5 % per year or more, including Burundi, Haiti and El Salvador. Deforestation removes the protective vegetation, usually leading to further consequences such as flooding, soil erosion from water and wind, and decreased replenishment of

[5] The reliability of environmental measures has been subject to much debate. For example, with respect to deforestation, World Bank and FAO estimates of deforestation in Indonesia in the 1980s differed by a factor of 3 (see Bilsborrow, 1992). A recent paper has questioned high FAO estimates of deforestation rates in 7 countries of West Africa by pointing out that the "original base year (1900 or 1950) estimates of forest cover were too high (Leach and Fairhead, 2000). The growing availability of satellite imagery promises to lead to much better estimates in the future, but substantial data processing and analysis is needed to convert satellite images to reliable measures of cleared forests.

underground water aquifers due to lack of vegetation to slow water runoff and the lack of tree roots to channel the water downward.

As for the overall proximate *causes* of the deforestation, on a global scale the World Bank (1991) attributed about 60% of recent deforestation in the developing world to the advance of the agricultural frontier, 20% to logging operations (including mining and petroleum), and 20% to fuelwood use.[6] The importance of these three factors varies greatly across regions, from one country to another, and from one region to another within countries, but demographic factors appear to be of some importance in both the agricultural extensification and fuelwood use (FAO, 2000). A study by Bilsborrow and Carr (2001) on Latin America based on cross-country data finds pasture expansion the major factor in deforestation in most countries of the region, but that the expansion of annual crops was also important in Central America. The latter is much more closely linked to population growth and its increasing food demands. However, there has not been an adequate quantitative assessment of the relative shares of pasture expansion vs. other agricultural expansion in relation to forest clearing across developing countries and over time.[7]

In this context, migration is involved in the ongoing process of deforestation on the agricultural frontier, though the subsequent *natural population growth* of migrant populations after they move to an area *becomes increasingly important over time* (see discussion of Ecuador, in section 4). The vast majority of the literature fails to even consider the role of fertility and natural population growth *in situ* on the loss of forest cover.

To the extent the poor are involved in the migration and settlement of the frontier--and they usually constitute the vast majority of migrant colonists--they are thereby implicated in the deforestation. But this may be said to be blaming the victim , since the migration of the poor to the tropical rainforests and semi-arid land frontiers is due to their lack of (access to) land or other (e.g., human) capital to sustain themselves. Furthermore, their migration to such ecologically fragile environments is often facilitated by roads constructed by logging or mining enterprises, often by multinational corporations to gain access to resources to extract for the global market.[8] Similarly, the poor throughout the Third World usually use fuelwood (or its derivative, charcoal)

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[6] Indeed, the search for wood has led to a virtual total elimination of vegetation around human settlements in some areas of the world, in concentric circles, steadily widening with population growth, and increasing the time it takes people (usually women) to collect fuelwood. A classic example is around the water holes in the Sudan, which followed from a misconstrued World Bank policy of promoting shallow wells for water extraction, which led to mining of underground water aquifers (Bilsborrow and DeLargy, 1991).

[7] Because of differences in land availability, responses to increasing rural populations in recent decades have differed from one continent to another, with more land extensification and rural-rural and rural-urban migration in Latin America and Africa and more intensification of agriculture in Asia (Bilsborrow and Carr, 2001).

[8] The effects of roads on facilitating in-migration to fragile ecosystems have been documented in a number of studies. See Rudel (1983), Rudel and Richards (1990), Chomitz and Gray (1995), Brown and Pearce (1994), and case studies reviewed in Section 4.

for their domestic energy needs. This is particularly true in most of Sub-Saharan Africa, rural Asia and parts of rural Latin America.

Soil desiccation is often mislabeled as desertification .[9] The removal of protective vegetation, whether of trees or shrubs or savanna grasses, renders the soil vulnerable to water and wind erosion, which may both destroy any remaining vegetation and lead to drying of the soil since there is nothing left to retain the water. Postel (1997) and Falkenmark (1994) describe the process and its possible linkage to the population growth of humans and ruminants (pastoralists and their herds), most notably in the Sudano-Sahelian belt across Africa. Nevertheless, desiccation on a smaller scale is occurring in many places in Asia as well, and even in areas of the Amazon denuded of vegetation and trampled by cattle where micro-climate changes with declining rainfall are occurring.

The third form of environmental degradation considered here, soil degradation, takes various forms, including soil erosion, soil desiccation, salinization of soils, and declining soil fertility. Although soil degradation is difficult to determine on a large scale, a global assessment of the extent of human-induced soil degradation has been made by the noted Wageningen Institute of the Netherlands (Oldeman et al, 1990). They estimate that 20 percent of all the vegetated land in the developing regions is degraded, much of it moderately to extremely degraded. Deforestation is seen as one of the major causes of soil degradation, estimated to account for 40% of the degradation in Asia and South America, 22% in Mexico and Central America, and 14% in Africa (but with the overall extent of degradation being greater in the latter two regions).

Land distribution is unequally distributed throughout the world, with the inequality of land distribution particularly severe in most countries in Latin America. The situation is described as one characterized by simultaneous domination of *latifundia* and *minifundia,* in which a few farms (the *latifundia*) control most of the agricultural land while most of the farmers have very little land (*minifundia*). Gini coefficients which measure the extent of land concentration are generally in the range of .6 to .85 for countries in Latin America. Moreover, as Leonard et al (1989) noted, the poorest 20% of the population in the developing countries also tend to live on low potential lands, that is, marginal agricultural lands with inadequate or unreliable rainfall, low soil fertility, and/or steep slopes. In country after country, even those that have had some land redistribution, such as Mexico and Bolivia, those who are better off have corralled the better lands, often valley lands (e.g., see Cruz on the Philippines, Stonich on Honduras). Thus _ of the poorest 20% in Latin America live on such marginal lands, while the figures are 57% in Asia and 51% in Africa. Hence it is not just the lack of land that contributes to rural poverty, but its *quality*. The fact that these lands are of low potential makes it likely that the poor, in using them, will also degrade them.[10] Once the poor have degraded lands in one area, they often migrate to

[9] I am grateful to Malin Falkenmark for pointing this out some years ago.

[10] Repetto (1986) describes a 6-fold increase in sedimentation in a West Java watershed since 1911 due mainly to

other marginal areas, such as tropical rainforests or semi-arid areas, and deforest and degrade those areas, creating a cumulative causation circle linking rural poverty, deforestation and land degradation.[11] Examples are presented in section 4 below.

In the Brazilian Amazon poor migrant settlers clear the land, find it yields only a few year s of adequate crops due to the poor quality soils, and then abandon the land to move on to degrade (clear) new areas, selling their originally cleared land to larger, mainly ranching interests. Sometimes the latter have taken over the land through violence or threat of violence (Schmink and Wood, 1993; PBS Television Series on Frontline, Decade of Destruction , 1993).

Population growth and migration linked to vegetation clearance is thought to lead to micro-climate changes in rural areas--declines in rainfall and therefore in agricultural potential due to deforestation--in the Andean valleys of South America, in the Himalayas, and reportedly even in the Amazon basin where forests have been cleared. The debate continues about whether overuse of marginally productive drylands for farming and grazing in the Sudano-Sahelian belt across central Africa has led to dessication of soils and a southern expansion of the Sahara desert.

Finally, up to 55% of all species on earth live in the tropical rainforests, so that recent large-scale intrusions of rural-rural migrants setting up farms there is having a devastating effect on biodiversity and on the world s gene pool, with possibly dire consequences for future human food production and medicines. Although human population increase and the activities of people also affect biodiversity through the devastation of species for food or pleasure (such as a number of fish species the past century), the main impacts are through damage to the rural environment via the destruction of ecosystems and *habitats* to expand the area used for human habitation, agricultural or energy production, transportation and recreation. Migration plays a fundamental role in these processes, whether preceding (inducing) or following them.

3. Conceptualizing the linkages between migration and the rural environment

Linkages between migration and the (rural) environment are complex and may take several different forms. It is useful to break them down into distinct types of linkages, drawing on two bodies of theory: (1) the theory of the determinants of migration, including examining the role of environmental factors on stimulating or forcing out-migration or on attracting in-migrants; and (2) the theory dealing with appraising the effects of migration on areas of destination, especially on the environment in those areas. The latter will also consider the effects of out-migration on the environment in places of (rural) origin. Note that while some migrants may indeed move from

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the poor population moving up steeper mountain slopes to clear forests to create farms as population grew: The most severe erosion was found on subsistence upland holdings of under 0.4 ha.

[11] The concept of cumulative causation was proffered by Myrdal (1963) in his political economy classic.

urban to rural areas, the numbers tend to be relatively small (see Table 3 above) and usually involve mainly return migrants, and are therefore subsumed here with the much larger numbers of rural-rural migrants.

(a) The Determinants of Migration

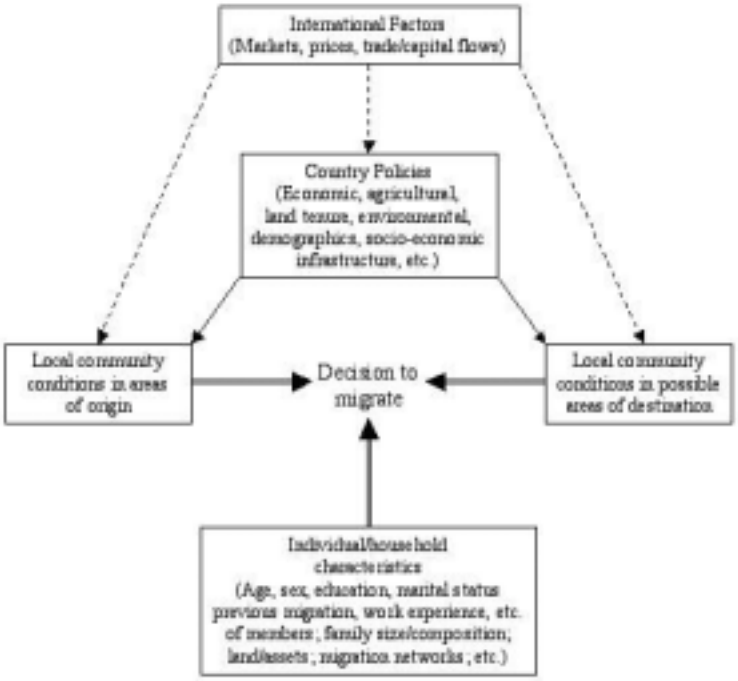
Approaching the topic of the linkages between migration and the rural environment requires first considering the factors that affect migration decisions. We thus need to examine the theory of the *determinants of migration*, to assess where environmental factors may fit in. Space does not allow more than a cursory summary of migration theory here. In essence, migration is affected by *differences* in economic opportunities and living conditions between places (and countries, for international migration), by people's *awareness* of those differences and desire to improve their lives by moving, and by their ability to act upon those desires. The main factors influencing desires to migrate are differences in employment opportunities, wage rates, and living conditions (geographers use place utility —see Wolpert, 1965); at the same time, psychological/emotional attachments to home/family, friends and community are major factors that keep most people from migrating. The awareness of differences from one place to another, the ability to migrate, and the cost of migration are all strongly affected by the distance to the potential destination, communications and transportation connections, education levels, and, in the case of international migration, by state policies.

The factors that affect migration have been categorized (Lee, 1966) as "push" factors (in the place of origin) and "pull" factors (in the place of destination). Both include environmental variables. For example, environmental push factors include both natural disasters (earthquakes, volcanic eruptions, hurricanes/cyclones) as well as human-induced environmental degradation (e.g., flooding resulting from deforestation of watersheds, salinization of soils due to prolonged irrigation, soil degradation from improper land use practices). Environmental pull factors may include the attraction of good farm land or of a more attractive natural setting or climate.

Traditional empirical research on migration has focused on the individual characteristics of persons that pre-dispose them (or not) to migrate, such as a person s age, sex or education (Sjaastad, 1962). Starting with Mincer (1978) and essays in DeJong and Gardner (1981), *inter alia*, the standard view focusing on migration decisions as made by individuals changed to view most migration decisions as household decisions, that is, as either made by households, whether to send a household member away, or to move the whole household with the migrant. At minimum, even individual migration movements came to be seen as affected by the characteristics of the household of the (potential) migrant in his/her place of origin. More recently, the theory has been further expanded so that now it is recognized that the *community or context* of the household where the decision is made is also relevant and should be explicitly taken into account in modeling migration (e.g., Wood, 1982; Bilsborrow et al, 1984; Findley, 1987; Massey, 1990). Although this has as yet rarely been done successfully (noted in review in Bilsborrow, 1998), the current *modus operandi* for modeling the determinants of individual or household migration is to view it as determined by characteristics at the (i) individual [*viz*., age, sex, education, marital status, work experience], (ii) household [household size and age/sex/education composition; amount of land and other business assets owned; income of other household members], and (iii)

contextual- or community-level [location of community and transport and communications linkages with possible destinations, employment opportunities and wage levels, land/natural resources, amenities and infrastructure, cultural norms, etc.]. The local community-contextual factors may themselves be seen as affected by higher level provincial and national policies, and the latter by international factors. For example, living conditions of coffee farmers in a community are affected by farm-gate prices the farmers receive from intermediaries for their sacks of coffee, which are in turn affected by government tax, subsidy, and export policies pertaining to coffee and inputs used in its growing, as well as by prices and demand in international markets. Changes in factors such as international prices therefore filter down through political levels and institutions at each stage until they reach local farmers. Figure 1 illustrates the hierarchical nature of migration decisions, and the relevance of both origin and destination conditions.

Figure 1. The Migration Decision



The relevance of *environmental* factors in influencing out-migration from rural areas can then be seen in the context of household and community-level contextual factors. Environmental factors may therefore operate either by affecting income-earning opportunities of household members at the level of the household farm or business (e.g., the amount and quality of land available), or through their effects on economic opportunities in the community. Thus soil degradation from excessive or improper use or from the ash of a volcano may provoke a household to consider leaving. Even if a particular farm is not affected this way, the community as a whole may be:

Natural disasters or soil degradation in the community reduce agricultural prospects and therefore the derived demand for labor and agricultural wages in the area. Human practices may sometimes be viewed as also making the place of origin less desirable in other, non-economic ways (such as via water or air pollution, deforestation). *Any* form of environmental change that adversely affects the productivity of land will tend to reduce agricultural incomes and stimulate out-migration. It is likely that in some studies of the determinants of out-migration based on household surveys, the reasons that people give for leaving that focus on their lower incomes may have a significant, *underlying* environmental aspect. Household surveys have not as yet examined these aspects, which requires more in-depth questioning about conditions faced by the person/household prior to migrating and the extent to which environmental factors are involved in deteriorating economic conditions or productivity. In such cases, the environmental degradation may be seen as a "root" cause and the decline in crop yields as only the proximate cause (Shaw, 1989, introduced this terminology in the population-environmental field).

(b) The Consequences of Migration

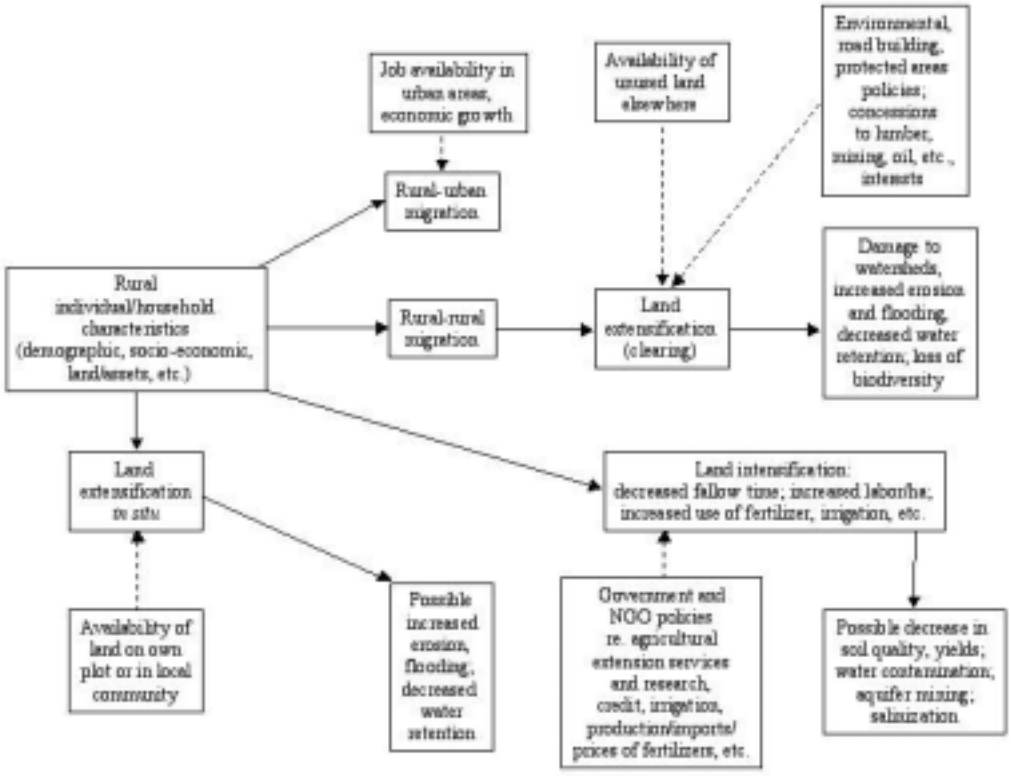
While there is a substantial body of theory on the determinants of migration, theory per se on the consequences is limited, with consequences usually studied only in terms of the impacts of migration on a wide range of possible indicators, including its effects on increasing population size, growth, and/or density; changing the composition of the population (such as by increasing or decreasing the education levels or productivity of the labor force, or by altering the relative supply and demand for labor); providing access to employment or higher wages; providing better access to services and amenities, etc. These are impacts at the individual and household levels, though there are also impacts at the community level on both communities of destination and origin (such as on wage rates, crowding, stock of human capital). The impacts are indeed multi-dimensional, with the effects actually investigated varying by discipline. The consequences may be viewed from the perspective of individuals, households, and/or communities, from the perspective of migrants and/or non-migrants, and for communities of origin and/or destination.

In terms of the consequence for rural areas of destination, it may be useful to recur to Malthus (1798) and Boserup (1965) as starting points, though their work focused on population and land use, and specifically on the effects of population growth on increasing population density and whether that increase in density tended to lower per-person living standards. The latter was the view of Malthus since he could not foresee the vast changes coming in the next century or two in agricultural technology. However, in another passage, rarely quoted, Malthus clearly stated that he saw (rural farm) families, under appropriate conditions, as responding to population pressure by *out-migrating in search of land* to clear for agriculture, that is, extending the agricultural frontier. That migration may be internal, within the country, if unused land is still available, or international, if not (Malthus, 1798, 1960 ed., pp. 346ff). Migration was thus seen as a mechanism for escaping from population pressures. In contrast, Boserup (1965) hypothesized that, under certain circumstances, farm families could be stimulated by increasing population density (pressure on living standards) to instead adapt their technology so as to use land *more*

intensively, and eschew the need to migrate. Davis (1963) and Bilsborrow (1987) subsequently formulated a broader "multiphasic model" that viewed out-migration as only one possible response to the growing pressures on living standards of a farm family resulting from population growth.

The elements above are useful to incorporate in a conceptual model of the linkages between the migration decision of a rural household and the possible environmental consequences in areas of destination, as illustrated in figure 2. Here we see that at any given time the household has certain endowments of people (defined by the age, sex, education, etc., of its members, and their number), land and other assets (which are affected by local and national government policies regarding land titles and agriculture), and locational attributes relative to access to a transportation system providing access to other communities and markets. These factors along with the characteristics of the local community (such as labor markets, services, and amenities) and its transportation linkages with *other* markets and communities influence farm production and incomes and non-farm incomes of household members, which together determines household income and welfare, as well as aspirations to seek change or not.

Figure 2. Rural Household Decision-Making, Migration, and the Rural Environment



The household must then be seen as continuously evaluating conditions in the place of origin and elsewhere to determine how to survive or cope in difficult times or to move to improve its standard of living. The possible forms of adaptation include, as a first option, further land clearing *in situ*, if any untapped land exists on the family's plot in the local community, including "open access" lands available to anyone (Bilsborrow and Geores, 1992). Of course, the latter becomes untenable when many farmers do it, and leads to resource degradation through a "tragedy of the commons" (Hardin, 1968). In addition, from one generation to the next, the agricultural plot may be subdivided among the children, resulting in land *fragmentation* and increasingly inadequate plot sizes (i.e., too small to support a family). Both of these options tend to lower living standards and stimulate further responses eventually. One other response short of out-migration is *land intensification*. Thus, following Boserup (1965), the effective land area may be extended by shortening fallow periods, or more labor may be applied per unit of land (increase weeding, build and maintain terraces and windbreaks), or more fertilizer, irrigation, etc. Each of these is adopted to increase productivity per unit of land, and may be facilitated by government policies or not, as noted by the dotted arrows in figure 2. These responses may also lead to environmental degradation, such as to declining soil fertility through overuse of soils in the absence of compensating practices such as fertilizer applications or crop rotation; to water pollution from runoff from excessive use of chemical fertilizers and pesticides; to mining (depletion) of underground water aquifers; and to salinization (build up of salt deposits) of soils from irrigation.

However, if the public policy context is not favorable to agricultural intensification--which is common in developing countries which are characterized by a strong "urban bias" in development policies (Lipton, 1977)--then the family has no alternative but to throw in the towel and leave its place of origin. The two types of out-migration possible are rural-urban migration, which depends on the availability of economic opportunities in urban areas; and *rural-rural migration*, which depends on the availability of land elsewhere in the country and on the accessibility of that land. The statistics in section 1 above show that in fact rural-rural migration continues to be a major aspect of population redistribution in many countries, and may be linked to agricultural extensification and extending the agricultural frontier through land clearing even when rural population size in the country as a whole is falling. This rural-rural migration has significant environmental implications to the extent it is directed predominantly to marginal, fragile areas, often made accessible recently through extensions of road networks. Depending on the type of ecosystem or biome in the destination area, this rural-rural migration may be characterized by the clearing of forests or other vegetation to establish croplands or pasture. This results in, more or less serious, damage to watersheds; reduced water retention and replenishment of underground aquifers; and increased surface runoff, flooding, soil erosion, siltation of dams downstream, and decreased soil fertility. While many of these consequences can be controlled or moderated by appropriate policies, most Third World countries do not have the necessary resources and technology.

Note that the arrows in figure 2 indicate *alternative* pathways, that the more one type of response occurs, the less pressure or tendency there is for the other responses, following Davis and Bilsborrow. And they do not exhaust the types of household decisions intended to maintain or improve welfare, which also include fertility decline and either temporary labor migration or permanent out-migration by one or more family members. In the latter case, most of the household remains behind and may expect to survive there or even improve its standard of living from the remittances sent by the migrant. The allocation of household labor in such a way across space and among more than one form of economic activity spreads risks, as seen in the peasant household survival theory (Arguello, 1981).

More important, the dotted lines in figure 2 indicate the crucial roles played by *contextual factors* in determining what decisions are made by rural households. These factors include local and national natural resource endowments, social and economic infrastructure, national and local government policies that determine land ownership and access to land, environmental policies and set-asides for protected areas, road construction, policies regulating (or not!) logging, mining and petroleum companies, etc. Such contextual factors and policies establish the physical context and rules of the game that determine the types of responses households are most likely to adopt at any given time.

While the discussion in this section is oriented toward situations of *growing* rural populations, we saw in section 1that more and more developing countries in the future will have declining rural populations in the aggregate. From a theoretical point of view, one should expect a certain degree of parallelism in the case of declining populations, in which land available per person/household rises. That is, microeconomic reasoning leads one to expect that this should raise rural wages, demand for and prices of its output, and therefore rural family living standards, and possibly even permit natural reforestation in "origin" areas to the degree less land is used. However, to the degree out-migration from rural areas is selective of the more educated and motivated, the decline in the average quality of the labor force may more than counter the positive effects of a lower labor-land ratio. In addition, this may still be more than countered by international factors or by the strong bias in government policies against rural areas, with a declining rural population having even less political power, resulting in even stronger urban bias. As more countries begin to experience declining rural populations, this will become an important topic for research.

The discussion above takes population growth as the initiating factor in the sequence of change, but it could also be economic forces or environmental degradation in the rural region of origin that creates the pressure on living standards and thereby stimulates the original response(s), including out-migration. Such forces are considered in section 5 below. In addition, the discussion is couched in terms of internal migration, though the theoretical perspectives regarding both the determinants of migration and its consequences apply equally to international migration. That is, environmental factors may contribute to international migration, especially if they occur in areas near the border, and the in-migration of international migrants may also affect environmental

conditions in places of destination. I am not aware of any explicit quantitative studies of the linkages in developing countries and hence only discuss the topic briefly in sections 4 and 5 below.

In the next section I critically review a number of empirical studies of particular countries and communities to identify the types of linkages observed in recent decades, including the roles played by contextual factors in determining the relationships and decisions adopted.

4. Impacts of migration on the rural environment in developing countries

This is the most important section of this monograph, reflecting the concentration of research on the impacts of internal migration on rural environments in low-income countries. The existing literature indicates the diversity of impacts varying according to the country context and type of ecosystem. While there have been important advances in the quality of research, most studies have continued to be based on inadequate demographic and environmental datasets, as well as difficulties in matching the two types of data for geographic areas (see Clarke and Rhind, 1992; Liverman et al, 1998), and lack of multivariate quantitative analysis. Many studies instead focus on one or two factors of particular interest to the authors, who then adduce evidence in support of their ideological stances either in favor of or in opposition to those factors. Some (if not most) of the research on population/migration effects on the environment suffers from such an a priori bias towards seeing population as either unimportant and overstated in the literature or as the main factor in environmental decay. Differences in the impacts observed from one study to another may thus reflect such biases as well as wide differences in the quality of data or the methodology used (the latter two being serious weaknesses in many studies).

The results of the review below indicate that the nature of the impacts varies according to the context and depends on such factors as natural resource endowments, local institutions and infrastructure, and government policy. While each study described below may have some broader applicability for other countries in the same geographic region or elsewhere experiencing similar proceses, this does not mean that each type of situation is equally common or important. I begin by assessing studies of the environmental impacts of colonists migrating to the rainforest frontier.

(a) Migration of agricultural colonists to the rainforest frontier

Settler migration to rainforest areas and the subsequent destruction of that habitat are a topic of rapidly growing concern. Migrant colonists, because of their numbers and their access to increasingly effective (and destructive) technology for land clearing (such as chainsaws), have been the direct or proximate agents of a significant proportion of the tropical deforestation occurring in the developing world. The discussion in this subsection is organized by geographic region, beginning with the region undergoing the most rapid deforestation of tropical forests, Latin America.

Latin America. The country which has been studied the most by far in the context of migration and deforestation is appropriately Brazil, which has 35 per cent of the world's tropical rainforests and where the extension of the agricultural frontier has been responsible for the largest annual volume of forests lost in recent decades (see section 1). However, it should be noted that many other countries, with smaller initial forest stocks, have been experiencing higher *annual rates* of deforestation, in Latin America and elsewhere. While the Brazilian Amazon region had long been settled by indigenous tribes, albeit sparsely, and parts had been exploited by the rubber tappers *(caboclos)* during the rubber boom a century ago, most was untouched and not settled "permanently" until after roads began to be constructed in the 1960s (notably BR-364 from the Southeast to Rondonia, and the east-west Transamazon Highway). In a country characterized by high rates of both population growth and industrial growth, national policy at the time promoted a westward expansion of people to tap the vast wealth of the Amazon, assert Brazilian sovereignty in border areas, and provide a release valve for peasants who had insufficient land and lived in densely populated areas elsewhere (especially in the drought-stricken Northeast). Several government- sponsored programs initially provided free land and food for six months in Rondonia and elsewhere to attract migrant settlers, but the effects of these programs were soon completely overrun by spontaneous settlers (Henriques, 1983; Hecht and Cockburn, 1990). Tax incentives for cattle also added to a speculative land boom. While plots made available to the initial settlers were quite large at 200 ha, the size of new settlement plots made available fell to100 ha. in Rondonia in the 1970s and to 50 ha. in the 1990s. Poor soils, transportation difficulties in marketing the produce long distances, lack of land titles and long delays in getting titles, and lack of credit for all but the big ranchers led many of the original settlers to experience declining yields over time on the marginal soils. They then sold out their holdings or even abandoned them in order to migrate either further into the rainforest where they would begin the clearing process anew on a new plot or moved to the boom towns of the region. Thus *rural-rural migration* within the Amazon basin has continued to lead to further deforestation, even as the rural population of the region ceased growing by 1990. In addition, ranchers, benefitting from the generous tax subsidies, often bought out the small farmers, and at other times forcefully removed them from the land (Hecht, 1985; Hecht and Cockburn, 1990; Schmink and Wood, 1993). The conversion of cleared small farms and abandoned lands to pasture for large cattle ranches--a far more extensive use of land than crops--has contributed to continuing deforestation in the 1990s.

Because of the expansionist policies of the government of Brazil in the Amazon (including road building and the creation of a new capital in the interior close to the rainforest), and because of the relatively low population density in the country as a whole, some argue that demographic factors have played no significant role in the deforestation of the region. While it is true that (increasing) rural population pressures cannot be considered a major proximate cause of recent deforestation in the Brazilian Amazon (since the rural population of the Amazon, as well as in Brazil as a whole, has been declining), this agnostic view disregards the effects of high fertility

and population growth *in areas of origin* of many of the migrant settlers to the Amazon. High fertility in the drought-stricken Northeast led to increasing population density and pressures on the land, given the context of extreme inequality in land ownership. Thus landholdings of most families became even smaller due to the division of plots among children. This combined with a series of droughts exacerbated rural poverty, providing a major impetus for out-migration in terms of push factors, with the pull factors of available land ultimately being important in attracting the migrants to the Amazon region. Although many migrants from the Northeast initially moved to Sao Paolo and other cities in search of work, once the new roads opened up the Amazon region, they moved on to the Amazon. Later the replacement of coffee farms by large, mechanized soybean plantations in the Southeast also forced many additional farm families to migrate to cities or to the agricultural frontier in the Amazon.

Thus in both instances rural-rural migration was responsible for the deforestation in the Brazilian Amazon, though the so-called driving forces were population growth and a highly unequal land distribution in areas of origin, misguided government policies (the tax subsidy for cattle was finally ended a decade ago), and changes in agricultural crops and technology (in the South), related to international markets. A key research issue in the Brazilian Amazon is to identify *who the new migrant settlers are* currently on the agricultural frontier, such as in the western state of Acre near the Peruvian border, northern Para, and the huge central state of Amazonas. Are they new rural-rural migrants coming from outside the Amazon, or are they farmers abandoning their existing plots in the Amazon moving within the Amazon region, as a result of declines in soil fertility and yields? With the substantial declines in fertility in most of Brazil since the 1970s (total fertility rates being halved, reaching essentially the replacement level of 2.2 for 2000-2005, according to the United Nations *World Population 2000 Wall Chart*), high fertility and high population growth in areas of origin are not likely to be significant factors in contributing to out-migration to the Amazon basin any more, though they did contribute to initiating the process.

Similar processes of migration to the rainforest frontier accompanied by large-scale forest clearing have been documented in a number of other countries in Latin America. In Guatemala, migration into the northern Peten resulted in the clearing of half the forests in the region during the period 1950-1985 (Leonard, 1987). More than in Brazil, high population growth in areas of origin may have played an important role. Thus, in the Guatemalan Altiplano and elsewhere, the agrarian structure was (and is) characterized by extreme inequality in landholdings. Thus the continuation of high rural fertility in the face of declining mortality since the 1930s appeared to lead to high population growth and increasing fragmentation of farm plots a generation later, in the 1960s and 1970s. This fragmentation resulted from partiable inheritance among increasing numbers of children surviving to grow up to form families and establish their own farm plots. This process is described by Bilsborrow and Stupp (1997), and documented by data from three successive sets of censuses of population and three censuses of agriculture in Guatemala over the period 1950-1980. Thus it is striking that the number of farms in the Altiplano increased little in the first intercensal period (1950-64) before the larger number of surviving children would have

reached the age of becoming household heads, at say age 25-30, but almost *doubled* in the 1964-79 intercensal period, when those reaching this age would have been far more numerous. Evidence on fragmentation is evident from the fact that the mean size of plots in the smallest land size stratum, those less than 2 *manzanas*,[12] fell from 1.0 to 0.7 during the second period, confirming the process of fragmentation. As plots of less than 5 manzanas (not to mention under 2 mz) were considered by SEGEPLAN, the Guatemalan Secretariat for Economic Planning, too small to support a family, this fragmentation further worsened rural poverty. The shrinking of plot sizes also contributed to growing rural unemployment and underemployment, as more people sought off-farm work, though this was also due partly to insufficient labor demand (hiring) on the large landholdings where half the land was idle. The combination of fragmentation of plots into uneconomically viable sizes and the lack of local alternative sources of employment pushed out-migration from rural areas, especially to both Guatemala City and the Peten, the country's last agricultural frontier. The process of deforestation in the Peten observed by Leonard (1987) has continued since that time, as seen in satellite imagery and as documented on the ground in recent household surveys, even in and around national parks and the Maya Biosphere Reserve (Sader et al, 1997). It is rural-rural migration that appears to continue to occur to drive this process of deforestation. Although the census data used by Bilsborrow and Stupp are suggestive of the origins of the Peten migrants being in the Altiplano, the evidence is only circumstantial. Barrientos and Fernandez (1996) state that the high growth in the Maya Biosphere Reserve (over 5 percent per year) is due to in-migration primarily from southern regions characterized by land inequality and commercial agro-export production of bananas and sugar cane, which forced people out. Data from the most recent census of population in 1994 should be examined to determine the sources of more recent migrant inflows (1989-94). Nevertheless, specialized *surveys* covering larger regions of Guatemala are desirable since they can yield information on not only the origins of the migrants but their motives for migration, land use practices in the Peten, environmental consequences, and current socio-economic situation. An ongoing study of Carr (2001), based on detailed surveys of households and communities carried out in 1998-99 around the Sierra de Lacandon National Park of the Maya Biosphere Reserve promises to provide some answers to these issues for one part of the Peten, but this type of study needs to be carried out on a larger and more representative selection of areas and households in the Peten. Information on the origins and motives is needed to develop policies to better direct it in Guatemala. Otherwise, the ecologically important remaining forests of northern Guatemala will be destroyed within two decades.

Elsewhere in Central America, important studies have been carried out in Panama, Costa Rica and Honduras. In Panama, migration to the forest frontier, mainly to establish cattle farms, led to deforestation along new roads (Heckandon and McKay, 1984; Joly, 1989), a process which has been extended southward in the 1990s to near the Colombian border in the Darien gap. In Costa Rica, decades ago migrants to the canton of Sarapiqu colonized forest areas and cleared them to

[12] A manzana is .7 ha, or about 1.5 acres.

plant cash crops or grow cattle. As a consequence, the population of Sarapiqu grew fourfold between 1963 and 1983, while the forest cover decreased from 70 per cent to 30 per cent, and pasture increased from 24 per cent to 57 per cent of the land area (Schelhas, 1996).

Indeed, the increase in pasture area has played a major role in most deforestation in Latin America (Bilsborrow and Carr, 2001). For example, in Southern Honduras, the government promoted the expansion of cattle ranching and plantations of cotton and sugar cane on lowland areas with good soils to expand export earnings. As a result, large commercial landowners were able to force smallholders to migrate to adjoining mountain slopes where they established new farms. This required that the migrant farmers clear the forests on the slopes, leading then also to the additional environmental consequences of increased soil erosion and flooding downstream. Because of low yields, the migrants have barely managed to eke out a living (Stonich, 1989 and 1990; DeWalt, 1985; DeWalt and Stonich, 1999; see also Humphries [1998] on cattle ranching in northern Honduras). However, the sample size of households is quite small in these studies.

Apart from Brazil, the main research on migration and deforestation in South America has been on Ecuador, perhaps partly due to its neighbors having serious problems of drug production and insecurity in their Amazon regions so that few roads have been built into them. In Ecuador, migration to the northern Amazon provinces and the subsequent deforestation by agricultural colonists began in the early 1970s with the construction of roads by petroleum companies to lay oil pipelines to extract oil. Those roads facilitated an influx of migrant colonists, 75 per cent originating in the highlands (Pich n, 1997; Pich n and Bilsborrow, 1999), 83 percent in rural areas. The population of the Amazon region grew at annual rates of 8 per cent in 1974-1982 and 6 per cent in 1982-1990, the latest available intercensal periods, in both cases more than double the rates for the country as a whole. At the same time deforestation in Ecuador, mainly in the Amazon, proceeded at a rate of 1.8 percent per year, the highest among the seven Amazon-basin countries (FAO, 1997). The overall estimated rate of deforestation in the country of 1.2 % per year in 1995-2000 (FAO, 2001) continues to be the highest in Latin America. This loss is particularly important from an ecological point of view because the western Amazon region that straddles southern Colombia, eastern Ecuador and Peru is one of the world's richest areas in terms of biodiversity.[13]

A probability sample of plots in the northern Amazon was selected in 1990 based on maps showing areas of migrant settlement together with the number of households originally allocated plots by the Ecuadorian government Institute of Land Reform and Colonization (IERAC). The settlement process was essentially spontaneous, but later legitimized by IERAC which at the request of a group of farmers in a particular area conducted surveys of the property sites to determine boundaries between plots. IERAC then provided provisional land titles (*certificados*

[13]Myers (1988, 2000) has called this region one of the world's 11 ecological "hotspots".

de posesion) to those who could pay the low fees per ha and prove occupancy by having cleared part of the land. Ultimately many attained definitive land titles from IERAC.[14]

The 1990 sample was selected to be representative of the rural colonist population in the main lowland area of colonization in the northern two Amazonian provinces in Ecuador, Sucumbios and Orellana--the area of most intense agricultural settlement in the country. Unlike the samples of households used as the basis for most studies of deforestation in Brazil and other countries, this sample is not a convenience sample based on households strung out along a road but is instead *representative* of the entire population in the area of colonization: About 40 percent of the 419 sample households for which data were obtained were in fact not located on any road but rather from 2 to 14 km away from the nearest road. This required that the interviewers in the 1990 survey often had to walk long distances and spend the night on the floor of the settler s wooden dwelling. Detailed questionnaires were administered in each household, to the land manager and his/her spouse, obtaining information about the migration origins of the settlers, reasons for coming, size of plot and title status, household composition, housing quality, land use in crops and pasture, agricultural technology, off-farm employment, etc. The survey found that, on average, 44 per cent of the 40 to 50 ha. plots had been cleared by 1990. Since the colonists had been living, on average, 10 years on those plots, the mean rate of clearance was about 2 ha per year. The dissertation of Pichon (1993) and a series of papers by Pichon, Bilsborrow and colleagues provide detailed findings. A multinomial statistical model of the determinants of differences in land clearing and land use of farmers was developed in which the dependent variables are the proportions of land in four mutually exclusive forms of land use--annual crops, perennial crops (mainly coffee), pasture (cattle), and forest. Variables found to be statistically significant included household size (more members meant more deforestation), soil quality, duration of residence, and, most strongly, distance from the nearest road (Pichon, 1997; Pichon and Bilsborrow, 1999). Most continued to be poor in the Amazon (Murphy et al, 1997) but reported themselves as being better off, probably because of at least having their own land and some assurance of enough food to eat. In addition to the effects of household size on land clearing, research by Marquette (1998) found effects of the family life cycle in Ecuador (as did McCracken et al, 1999, on the Altamira area of the southeast Brazilian Amazon).

A follow-up household survey in 1999 offers the opportunity to examine in more detail the linkages between the migrant settler population and deforestation and the determinants of changes in the interim. In this project a satellite time series since 1973 was also obtained, permitting measurement of changes in land use over time at a larger, regional scale. In the 1999 survey, household plots were geo-referenced using GPS devices (also done in the Brazil studies of Moran and colleagues, cited above) and the data linked in a GIS with digitized data from topography, hydrography, soil, road and political maps of the region. Interviews were carried

[14]The law specified that one should clear 50 percent of more of the plot to establish a claim to it, but this was never enforced.

out with all families managing at least one hectare of land on any part of the original 419 sample plots, providing longitudinal data. Although analysis based on the new survey data has not been completed, it is clear that many of the original plots have been subdivided since 1990, due to both land sales to new in-migrants and subdivision among children as they became adults. Overall, the population living on the original sample plots increased by over 50 percent during the nine year period (Murphy, 2000). At the same time, the mean proportion of the plot cleared increased from 44 to 57 per cent, linked to the increase in population and in population density on the plot (Pan and Bilsborrow, 2001). Ongoing research is looking further at the causes of land clearing both cross-sectionally and over time at scales ranging from the individual subdivided plots, to the original plots of 40-50 ha, the community, and the region as a whole based on pattern metrics analysis. The fact that the average size of settler plots declined to about half that prevailing in 1990 has resulted in far more families having someone working off-farm to make ends meet--the percent with someone working away from the farm rose from 35 to 57 in the brief period. This is also associated with the rapid growth of towns in the region, providing more opportunities for off-farm employment, and improvements in roads, providing easier access to those towns. Linkages between land clearing and land use and urbanization processes in the Amazon and other countries undergoing land use changes at the agricultural frontier present a fascinating and untapped topic for research.

The data obtained to date are permitting detailed analyses of the factors responsible for changes in land clearing and land use by migrant households within the Amazon region, which is useful for developing better demographic, agricultural, environmental, and socio-economic policies for that region. However, these data are not sufficient to determine *why the migrants left their places of origin* in the first place, and therefore tell us little about what policies are needed to alter (e.g., reduce or redirect) those migration flows. To determine why migrants left, data on non-migrants in places of origin are needed to model the migration decision-making process (see Bilsborrow et al, 1984, 1997). Evidently, the Ecuadorian government policy of according priority to the extraction and export of petroleum from the region led to the building of roads linking the Amazon to other parts of Ecuador, which made access to the region possible. Given the high concentration of landless and near-landless families in the Sierra or Highlands, which was the product of high fertility and extreme inequality in the distribution of landholdings (Gini coefficient of .85), a pool of persons ready to migrate in search of land was already available. Thus, population pressure on existing agricultural land and the distribution of that land appear to have been key factors responsible for the out-migration from the Sierra, and hence ultimately for most of the deforestation in the Amazon basin of Ecuador.

In virtually all cases where environmental degradation has been caused by forest clearing by migrant colonists in Latin America, the colonists have been low-income families migrating in search of land. However, the land in tropical rainforests is usually of poor quality so that migrant farmers have rarely risen above the poverty level. Thus, despite the considerable environmental loss suffered by the country, the extent of poverty has not fallen (Murphy et al,

1997 on Ecuador; Ozorio, 1992 on Brazil). Of course, there are other direct agents of deforestation besides poor migrant farmers, including cattle ranching, mining, and logging. In the Amazon region and elsewhere in Latin America, the clearing of forests for pasture by commercial landholders and large ranchers has accounted for much deforestation, as noted before (Bilsborrow and Carr, 2001). Thus in the Brazilian Amazon, Wood et al (1996), based on a cross-sectional statistical study of aggregate data for 279 *municipios*, found rates of deforestation linked to levels of in-migration, but the effects of large farms and ranches was much greater than that of small farmers growing crops. A subsequent study of Walker et al (2000) found that, along the Transamazon Highway, the decline in the prices of major cash crops (cacao, black pepper, rice, etc.) relative to the price of beef contributed to small farmers switching land to cattle. Thus in 1976 an earlier investigator (Homma) found an average small farm had 6.4 ha in pasture and 2.5 ha in annual crops, while by the late 1990s the figures were 37 ha in pasture and 4.1 ha in crops. Thus the ratio of land in pasture to land in crops rose from 2.5 to 9.1. This study shows the importance of linking studies of household behavior with larger forces at play, as indicated in Figure 1 above also.*Asia*. Although there has been less relevant research on Asia and Africa than on Latin America, a number of important studies have been carried out. One of the countries most studied is, again appropriately, Indonesia. Indonesia is the world's fourth most populous country and third in terms of area in tropical forests, and has been experiencing the second highest annual volume of forest loss (section 2). Since the time of being a colony of the Dutch, the extreme disparity in population density between Java-Bali and the rest of Indonesia (the "Outer Islands") has been of concern, with density in the former in 1980 roughly 800 persons per km2 compared to 4 to 80 persons per km2 in the Outer Islands.[15] With three-quarters of all land in Java already in agricultural and other uses, little land remaining in forests, a mean plot size of only 0.25 ha. (barely enough to support a family) and often suffering from erosion (Barbier, 1990), 40 per cent of the rural population landless, and high rural poverty (estimated at 40 per cent in 1984 by the World Bank), in the early 1970s the government of Indonesia initiated a "transmigration program", the largest directed albeit mainly
voluntary colonization program of the twentieth century. The purpose was to recruit families from Java to be resettled on the Outer Islands. Migration under the program peaked in the 1980s but continued at low levels during the 1990s. About 2 million sponsored migrants were resettled from Java to Sumatra and Sulawesi by 1990, most poor and half landless. To help families get started, the government cleared 1- 2 ha plots per family and provided seeds, farm tools and food for the first 18 months. In a survey 3/4 reported themselves as being better off after migration. However, the adequacy of sites had usually not been appraised before the families moved in, with the result that half of the sites proved inadequate because of poor soils or because they were already occupied (Whitten, 1987).

Moreover, the transmigration program was so well publicized that it led to at least twice as many *spontaneous* migrants moving to the settlement areas as sponsored migrants. The impact of the

[15]The Dutch recognized early in the twentieth century the desirability of redistributing population and promoted it.

spontaneous migrants on the forests was usually considerably greater because they were not subject to government monitoring. Although this spontaneous migration therefore greatly magnified the environmental impacts, the fact that 70 per cent of the transmigration sites had been cleared or logged prior to transmigration did reduce the impact. Overall, forest losses were estimated at 2,400 km2 per year during the 1970s and 1980s, amounting to about 60 per cent of the total deforestation in Indonesia during that period. In the 1990s, national environmental policies were adopted in Indonesia, along with the creation of national parks and the virtual suspension of the organized transmigration program, but illegal logging, road construction and further spontaneous migration have continued to lead to substantial additional deforestation (Wells et al, 1999; FAO, 1997, 2001).

A crucial topic for research especially on Indonesia is to determine the longer term ecological consequences of transmigration, as well as of the spontaneous migrants.[16] Important questions are whether the transmigrants continued to clear additional areas over time (extending their initial deforestation) and by how much; or did they intensify agricultural practices, or increase off-farm employment as a supplementary source of household income? It will be useful for this purpose to compare demographic data for areas as small as possible (to come as close as possible to matching areas receiving transmigrants in the Outer Islands)--certainly at the level of *kecamatan* (subdistricts) if not for villages-—for which demographic and other data are collected in a village census undertaken at the same time as the decennial population census. But it would be even more useful to design and undertake a specialized sample survey of transmigrants to determine their demographic permanence and dynamics, economic situation, land ownership and use, and environmental impacts. Only such a survey will allow an accurate appraisal of the longer-term environmental consequences of Indonesia s massive rural-rural migration program.

The Asian country that has probably received the most attention in terms of research on migration and environmental decline is Thailand. Thailand experienced the highest *rate* of deforestation in Asia during the 1980s, which led to debate about who was responsible and therefore what policies to adopt. Thus those blaming logging companies primarily called for a ban on logging, or on logging exports, while those attributing deforestation to the expansion of the agricultural frontier called for resettlement programs or controls of new settlements by the military. Panayotou and Sungsuwan (1994) point out that such thinking focuses on the *sources* but not the (root) *causes* of deforestation (p. 193). They develop an economic model based on

[16]Along with this, it would be useful to determine the extent to which the spontaneous migrants migrated *because of* or following the transmigrants. How often were they close family members, and moved to the same transmigration areas? Did they hear about those areas and become motivated to go there by the transmigrants? How numerous in fact are they compared to the transmigrants (are they really 2-3 times as many, as reported)? What kinds of settlement, and land use practices, have they engaged in? Are those practices really more environmentally destructive than those of the sponsored transmigrants? What kinds of relationships (including land conflicts) have they had with the transmigrants, and with the local populations living in the area previously? Have they tended to stay or return to places of origin, or migrant onward? Where, and with what consequences?

demand functions for logging, fuelwood and agricultural land, and use it to empirically estimate the determinants of deforestation in northeast Thailand, the part of Thailand which has undergone the most rapid deforestation (its forest cover fell from 60 percent in 1952 to 15 percent in 1982 (*op. cit*., p. 201). Their work is novel in using measures of forest cover, the dependent variable, based on Landsat images, for four points in time, from 1973 to 1982. Data for the 16 provinces in the Northeast are pooled for the four years to estimate the model.

The results are striking, showing population density as having by far the strongest association with forest cover, followed by the price of wood, total income (Gross Domestic Product) of the province, and distance from Bangkok (all significant in this ecological regression at the .01 level), with three other variables less important--the density of rural roads, mean rice yields and crop prices. As the authors note (pp. 204-5), the results for population density suggest powerful effects of the human population seeking to satisfy its needs as a major determinant of land clearing. These needs are noted as primarily agricultural land and fuelwood, the major source of energy for domestic consumption. One might be tempted to interpret the results for population density as indicating the effects of in-migration on deforestation except for the fact that this is a very poor region of Thailand characterized instead by both permanent and seasonal *out-migration*. But the methodology used is more rigorous than that used in the vast majority of studies and bears further refinement and testing in studies of cross-sectional (ecological) data in other regions. Results for population density in such studies would be suggestive of the effects of in-migration on deforestation in areas where population is growing significantly because of in-migration.

Among the other studies on Thailand is one based on data for 58 provinces (excluding those close to Bangkok) from continuous population registers, road maps and satellite images digitized for various dates over the period 1976-1989 (Cropper, Griffiths et al, 1997). The authors looked separately at the effects of population pressures and road building in the northern and southern provinces. The northern provinces had generally steeper slopes and the southern ones poorer soils. They found population pressures had more impact on deforestation in the north. A 10 % increase in agricultural households was associated with a 4 % decline in forest area in the north but only a 2.3 % decline in the south. On the other hand, road building had more effect in the south, a 10 % increase in roads being associated with a 11 % loss of forests in the south vs. 2 % in the north (the latter relationship in fact being not statistically significant). Evidently both road building and population pressures are important overall, but their effects vary by context.

The fact that fertility levels in Thailand have fallen to low levels (total fertility rate of 2.3 in 2000) makes it even more likely that changes in density in the future will be linked to migration. Non-demographic factors are also likely to play increasingly important roles, with logging becoming more important than the expansion of the rice area. Changes in agricultural technology and in cropping patterns also affect deforestation. In Nang Rong district in northeast Thailand, the rise in demand for cassava as a livestock food in Europe led to an expansion of the area in

crops at the expense of hillside forests in recent decades, which helped support a population growing from natural increase. Thus land clearing occurred primarily as a result of external factors, with migration playing no role, there being mainly seasonal *out*-migration to Bangkok but little permanent in- or out-migration.[17] More recently, the creation of a new form of drought-resistant rubber has led to new plantations along the Mekong River in Thailand, attracting migrants and leading to some replacement of forests by plantation trees.[18]

In other studies on Asia, in the southern hill region of Nepal, settled after a successful DDT campaign to reduce malaria, migrant colonists moved in, and the clearing of forests ensued (Shrestha, 1990). Frontier migration also propagated landlessness, though mistaken government economic policies and the institutional rigidities of wealth distribution and the caste system also contributed (Dignan et al, 1989). During the first important migration movement in Nepal in the mountains, as well as during the more recent migration to the Terai (the great turnabout --cf. Hrabovszky and Miyan, 1987), substantial clearing of forests occurred, which led to increased soil erosion (Ojha, 1975). In Bangladesh, it is widely reported that the greater frequency of floods and the increased damage caused by them in the 1990s is the result of extensive forest clearing up river in the watersheds of India and Nepal (e.g., Rashid and Kabir, 1998). That clearing is linked to human migration into those watersheds and the clearing of forests for agricultural plots and use for fuelwood. In southern Sri Lanka, population growth is said to have led to higher population density and fragmentation of landholdings and landlessness, stimulating out-migration, mainly of young families searching for (and often clearing) land in other rural environments (Vandesemb, 1995).

In the Philippines, Cruz (1997) used data from population censuses and forest inventories to study relationships between population dynamics and forest cover from 1950 to 1990. She notes how government natural resource policies, rapid population growth, land tenure and landlessness, and economic policies contributed to worsening rural poverty, creating pressures for out-migration. As the agricultural frontier in the lowlands of the Philippines was essentially closed by the mid-1970s (*ibid*., p. 79), continuing population growth led to out-migration from rural areas. While much of that was to urban areas, eventually growing urban unemployment led to growing rural-rural migration. Most of this has been to frontier forest areas, mainly in the highlands, a process which seemed to be accelerating over time: The total number of new migrants to upland areas in 1980-90 was three times that in 1960-70. One result is that population growth in the highlands was double that of the country as a whole in 1970-80, resulting in the population of the highlands reaching a third of the total by 1990 (p. 76). The process of migration to the frontier has led to the displacement of indigenous communities (Magdalena, 1996), which has

[17]Personal communication, Barbara Entwisle, September 19, 2001. Entwisle, Rindfuss and Stephen Walsh are carrying out a large longitudinal project in Thailand that examines population, migration and land use, the results of which will be most interesting (see Entwisle et al, 1998).

[18]Personal communication, Gayl Ness, March 18, 2001.

also occurred extensively in many other countries, including throughout the Amazon basin, as noted in the discussion above for Brazil and Ecuador.

Cultivated upland forest areas, which accounted for only 10 percent of the total cultivated area in the Philippines in 1960, accounted for 30 percent in 1987 (p. 79). Cruz notes that the lowlands came to be increasingly under large landholdings devoted to cash crops, such as sugar cane and to cattle grazing, so that the growing rural population could find new land only in upland areas where they cleared forests to establish agricultural plots. The deforestation that resulted led in turn to substantial erosion, increased flooding, and loss of biodiversity (Cruz et al, 1992). The key root causes of the deforestation were noted to be not only high population growth and inappropriate policies, but especially the land tenure situation in the lowlands in which (the good) land was highly unequally distributed, with most of it being in large holdings dedicated to export crops and cattle. This resulted in most of the farmers having uneconomically small farms or being landless, pushing them to engage in rural-rural out-migration to the highlands (Cruz, 1997).[19]

Africa. Rural-rural migration also figures prominently in a number of studies on Africa. Netting et al (1989) describe the changes between the 1950s and 1980s experienced by the Koyfar of the Jos Plateau, Nigeria. In response to expanding market opportunities--and not induced by population pressures or assisted by government policy--they expanded food production (viz., yams) by migrating to the nearby fertile Benue plains and switched from shifting cultivation in forest clearings to permanent, intensively tilled and fertilized, family farms in areas cleared of forests. They
took advantage of good, available lands, expanding markets, and their own cultural attributes (individualistic, work-ethic) to achieve economic progress, albeit with environmental consequences.

In a study similar to that of Honduras described above, the spread of cash crops (especially coffee and cotton) stimulated by government policy in several regions of Tanzania led to substantial rural-rural migration to the Usangu Plains, accompanied by depletion of vegetation. The human population of the Plains rose five-fold between 1948 and 1988 and the number of cattle doubled. However, the ecological deterioration (loss of forests) that occurred was viewed as also partly due to insecure land tenure and the absence of social institutions for regulating resource access and use (Charnley, 1997). Charnley introduced the concept of "cascade effect" to refer to cases such as this, in which environmental displacement of populations leads to their migration elsewhere where they create new environmental problems. She postulates that the latter are likely to be more complex and difficult to solve, so that environmental problems should be solved in their source areas whenever possible.

[19]Kummer et al (1994) write that land degradation in the Philippines may be exaggerated, and at least in the uplands of Cebu has turned the corner, with reforestation beginning.

Two other studies on Tanzania also provide relevant findings. Madulu (1996?) notes that resettlement strategies of the socialist government to relieve population density ignored the root causes of pressures on land being population growth. Population grew by 213 % in 1948-88, reducing farmland from 11.8 to 3.8 ha per family and increasing landlessness. A similar view is espoused by Kaoneka and Solberg (1997).

In Malawi, Kalipeni (1999) observed effects of migration on the environment as well as the converse. Thus substantial rural-rural migration occurred between 1972-73 and 1990-91, primarily from densely populated rural areas to sparsely populated rural areas. Cumulative deforestation was 44 percent during the same time period. Under the prevailing conditions of rapid population growth (3.5 % per year), growing rural population pressures are leading to a multiphasic response (section 3), with land intensification occurring in some areas (e.g., double cropping in Chiradzulu district, more use of fertilizers and intercropping in other districts with dense populations), marginal lands being brought into cultivation, outflows of male seasonal migrant labor, permanent out-migration to the agricultural frontier, and most recently, the beginnings of a fertility decline (though this is said to possibly be due to worsening economic and environmental conditions instead). However, Kalipeni notes that the data available on intensification are extremely limited, and the evidence on the linkage between migration and deforestation is circumstantial rather than documented by direct data. This is in fact likely to be the case for most of the literature, which is *not* reviewed here.

In Kenya, in the Lake Elementeita watershed in the central Rift Valley, data sources which are coming into increasing use in studies of the environment, LANDSAT satellite imagery and vegetation surveys, are used by Mwaura and Moore (1991) to examine the environmental effects of high population growth (5.7% per year in the 1960s-1970s, much from in-migration). In the short period 1973-84, as much as 58 percent of the forest cover in the study area of 153 km2 was lost. In Rwanda, population data from the 1948 and 1978 censuses are cited to show, via descriptive analysis, how population growth led to the spread of the agricultural frontier into upland areas, resulting in deforestation, as well into lowland marshes (Cambrezy, 1984).

There are a number of other studies on Sub-Saharan Africa which report negative effects of either population pressure (measured loosely as high population growth, or increase in population density--the latter being the desirable variable to use--or sometimes not defined at all) or of in-migration (rural-rural) on environmental degradation, but few are based on much data or theory.

It should be noted that deforestation can also be caused by populations seeking fuelwood to meet their energy needs, and that this is common in rural and some urban areas throughout the Third World, and especially in Africa. The poor are especially dependent on fuelwood, as are certain migrant groups, such as displaced persons and refugees. In situations of conflict or major natural disasters, large numbers of rural dwellers are often forced to move and seek refuge in other parts

of their own country (displaced persons) or in another country (refugees). In central and eastern Africa, west-central and southeast Asia, and parts of Central America, large populations of internally displaced persons and refugees have had to live in recent years in makeshift camps for long periods. Deforestation has resulted from the use of nearby forests for fuelwood, and there has also been depletion of surface and underground water deposits (Sessay and Mohamed, 1997).

(b) Migration and impacts on desiccation in dryland areas

Population growth due to both natural population growth (difference between fertility and mortality) and in-migration has also been linked to vegetation loss in dryland areas, with most of the work being on Sub-Saharan Africa. However, many examples of the impacts of migrants on dryland areas exist for Asia and Latin America as well. An example in Latin America is that of colonists settling in communal farms called *ejidos* around the Calakmul Biosphere Reserve in the Yucatan Peninsula, Mexico. Environmental degradation has resulted from the use of crops and technologies inappropriate for the area (Ericson et al, 1999).

There have been many studies on dryland areas in Africa, where the debate continues about whether the damage to the vegetation of the Sahel in recent decades is mainly human-induced and due to in-migration or part of a natural cycle (Faulkingham and Thorbahn, 1967; Granger, 1982; Postel, 1997). Nevertheless, there is little doubt that pastoralists and the animal herds they depend on have both increased substantially in recent decades and have frequently had to seek additional grazing lands. In some areas the decline of vegetation in the northern Sahel has forced nomads and pastoralists to take their animals further south, where they are increasingly competing for land and water with sedentary rural populations, increasing pressures on resources. The resulting conflicts have led governments to attempt to settle pastoralist populations, a strategy that has met with mixed success.

In Tanzania, 45 percent of the country s area was said to be desiccated by 1980, largely due to the in-migration of people with their animals to semi-arid regions (Darkoh, 1982). A study on protected areas in neighboring Uganda (Marquardt, 1994) found forested areas depleted by migrants settling there. In Kenya, Oyaya (1998) finds increasing population density led to changes in land use and land tenure systems, resulting in degradation and marginalization of land (declining soil quality and water catchment areas). He focused on the Maasai in Kajaido district, basing his conclusions on analysis of data for 290 households—one of the few studies in Africa that sheds light on the relationships of this review which is based on a large sample of decision-makers. An earlier study on the Maasai in Kenya (Talbot, 1986) reports population growth led to demands on rangelands beyond their carrying capacity under traditional management systems, with the result that such demands rose faster than institutions could adapt. The present problem is further complicated by the influx of farmers seeking farmland and competing for Maasai land. As a consequence, migration is contributing to increasing pressures on land and scarce water resources, contributing to land dessication. The creation of nature reserves which are off-limits to

agriculture has further increased competition for land and water in Maasai areas of Kenya and Tanzania.

The Sudan, albeit with a population density less than 10 persons per km2, is an interesting case, with some scholars considering it to be already at its carrying capacity because most of its territory is arid or semi-arid. The Gezira project, the world's largest agricultural irrigation scheme, has displaced pastoralists from their traditional seasonal grazing ranges, while the draining of wetlands to create other irrigation schemes has attracted migrants to the east. The Sudan has lost three quarters of its original forests, mostly since 1950, and continues to lose forest cover at a high rate (see section 2). While some deforestation is due to the extensive use of fuelwood for cooking, the arrival of refugees and other migrants to previously unexploited lands has played an important role as well (Ibrahim, 1987; Little, 1987; Bilsborrow and DeLargy, 1991).

The case studies reviewed above indicate that migration to marginal and fragile areas can result in deforestation and other forms of environmental degradation. However, factors other than migration are often the main precipitating factors, including the actions of governments, national and multinational corporations (logging and mining enterprises), and large-scale ranchers responding to national and international demands for high quality wood, beef, and other forest and agricultural products. The roads and infrastructure these actors construct have usually facilitated the arrival of migrants (see case studies of deforestation above). More generally, governments often alter areas with the specific goal to attract migrants, for instance, by constructing dams for irrigation in the eastern Sudan, northern Mexico, northern India, central China (the huge Three Gorges project) and coastal Peru, though other populations may be displaced in the process. The creation of national parks and protected areas, to the extent successful in keeping populations out, leads to higher pressures on resources in other nearby areas, often buffer zones, resulting in increased deforestation or desiccation in those areas.

(c) Impacts of out-migration on areas of origin

The discussion here is not complete without considering the environmental impacts of out-migration on the *rural areas of origin*. Theory suggests that the effects should be positive due to favorable change in the person-land ratio. Reduced pressures on resources might even facilitate natural reforestation, though there has been little research on this. While there have been few studies on the effects of out-migration on areas of origin (rural areas being of particular interest here), there are a few studies that whet the appetite for more. Thus, for example, in the Camacho valley of Bolivia out-migration led to less intensive grazing and improvements of the environment (Preston, 1998). In Indonesia the transmigration program had as an explicit goal the easing of demographic pressures in areas of origin, including the reduction of pressures on forests and water supplies in upland areas. And yet, although more than 2 million people were moved by the transmigration program, the population of Java-Bali still rose by 10 million due to natural

increase. Consequently, the environmental benefits from the reduction of population pressure must have been much less than anticipated, though there has apparently been no study of this.

In several contexts the environmental consequences of out-migration have been found to be *negative* in areas of origin. In the Peruvian Andes, out-migration led to a depletion of the labor supply which made it hard to maintain terraces, and thereby resulted in increased soil erosion (Collins, 1986). A similar outcome was observed in an island community of Kenya in Lake Victoria (Conelly, 1994). Finally, in Gabon, near the Gamba Complex of Protected Areas, the out- migration of young persons searching for employment in cities and in the oil sector is reported to have disrupted community-based conservation projects (Freudenberger et al, 1999). The usual positive selectivity of migrants also may contribute to negative effects in areas of origin, on not only the environment but also on the lives of those remaining behind. Indeed, a number of studies on southern Africa find the out-migration of males to work in the mines and cities of South Africa has disrupted family lives and led to (ecological) degradation of farms, even as it has led to increased autonomy and decision-making by the women left behind.

(d) A Note on migration and biodiversity

The relationships between human migration movements and biological diversity on the planet are attracting growing interest, due to the increasing size and mobility of the human population, the ongoing loss of biodiversity and the rapid creation of so-called protected areas (the term coined by the International Union for the Conservation of Nature-World Conservation Union) for both national parks and other protected areas such as nature reserves and forest reserves. The area of the earth in protected areas has probably doubled in the past decade. And a report of the IUCN released in September. 2000, stated that 11,000 species of plants and animals face immanent extinction, and that the current human-induced extinction rate is 1,000 to 10,000 times that which occurs under natural conditions.[20] The countries with the most threatened mammals and birds are said to be Indonesia, India, Brazil and China, much of this due to habitat destruction by human intrusions. Major international environmental organizations such as Conservation International, The Nature Conservancy, the Worldwide Fund for Nature have supported looking into the linkages between migration movements and intrusions into protected areas, and how to measure and monitor migration impacts.

But this is hardly a new theme: Throughout human history, migration movements have been linked to biodiversity losses. A recent study by Cincotta and Engelman (2000), although focusing primarily on population size, growth and density (and not even defining migration in its glossary of demographic terms), provides a brief overview of the effects of past human migrations (pp. 24ff): There is clear evidence that human hunters played a role in extinctions as far back as 10,000 years ago, and perhaps even 50,000 years before the present...[even though] there may have been only 5 million humans. Thus within a thousand years after the first

[20] *New York Times*, September 29.

settlers were purported to have arrived across the Bering Strait land bridge about 12,000 years ago, 73 percent of large mammals were hunted to extinction in North America, and when the migrants continued into South America, 80 percent of its large mammals may have disappeared. Similar losses occurred earlier in Europe and Asia.

More recently, there is a widespread belief and substantial evidence that human migration into and near the many new protected areas is having an impact on degrading those areas and causing loss of biodiversity. This appears true of protected areas in Madagascar, East and South Africa, Indonesia, Thailand, India, the Amazon, the Galapagos Islands, Mesoamerica, and many other places, though documenting the loss or disappearance of specific species is difficult and expensive and linking it to intrusions of human populations is not always straight-forward. The Forest Fragments Project of Lovejoy (*ibid*., p. 40) in the northern Brazilian Amazon sheds light on the impacts of migrants by showing the relationship between the size of the protected area or plot (varying from 1 ha. to 1000 ha.) and species presence. While small areas can preserve most species, much larger areas are needed to protect the large species. Thus small, fragmented areas, such as areas affected by migrants intruding into them, may often suffer only limited biodiversity loss in terms of number of species but those species lost may be key ones. Thus habitat disturbance, fragmentation, and outright habitat loss, taken together, currently constitute the leading direct cause of extinction (p. 42). Cincotta and Engelman observe that a number of studies have linked migration to habitat loss, including the destruction of tropical rainforests. They also examine the demographic dynamics of the 28 main biological hotspots (as determined by Conservation International) on the planet, and note that population density and population growth are both much higher on average than on the rest of the earth (density of 73 persons per sq km vs. 42, population growth of 1.8 vs. 1.3 percent per annum). And some areas with low density, such as the Amazon and Congo basins have extraordinarily high population growth rates (4 and 3 percent, respectively: pp. 42-43).

Given the importance of migration as a potential factor affecting protected areas, it is desirable to develop monitoring systems for keeping track of migrants and their effects around such areas. Ericson and Bilsborrow developed such a monitoring system for the Calakmul Biosphere Reserve in the Yucat n Peninsula of Mexico. The Calakmul Biosphere Reserve is important for biodiversity conservation because it constitutes a large part of a larger system of protected areas known as the La Selva Maya, which joins Mexico, Guatemala and Belize to form an ecological corridor of over two million hectares stretching from the central Yucat n and the Belize forests south (Ericson, *et al.* 1998). Created in 1989, it covers 800,000 hectares, including core and buffer zones. Ecologically sustainable production activities are allowed in the buffer zone but not in the core zone. The population in the buffer zone as well as in nearby towns has been growing rapidly since 1990 due to a heavy influx of migrants, some fleeing the troubled nearby state of Chiapas, as well as high natural population growth: Some communities are expected to double their population in 3-7 years. The population living around the reserve is estimated at about 25,000 people (Ericson et al, 1998). Many people living in and around the reserve are rural-rural

migrants, *pushed* from their places of origin in recent years by lack of land, lack of employment, displacement by commercial agriculture, ecological catastrophe, and social unrest, as in the case of Chiapas. A new wave of in-migration, mostly government and service-industry workers, is underway now with the recent establishment of Calakmul and its nearby administrative center of Xpujil, the strengthening of infrastructure, and the development of tourism. While population density is still low around the Reserve, the potential ecological impact of a growing population is large because the carrying capacity is low due to its semi-arid climate and poor soils. A methodology for monitoring population growth, especially in-migration, and its environmental impacts was proposed to WWF (Bilsborrow and Ericson, 2000), based on the administration of short questionnaires to samples of key informant households every 12 months in representative sentinel ejidos. The system is intended to make possible an inexpensive assessment of population change, the extent to which it is due to migration, and changes in land use and the environment, with implications for policy/ameliorative measures. Such a methodology could be used broadly around other protected areas in Mexico and elsewhere, adapted to country/local community conditions.

5. Effects of environmental change on out-migration from rural areas

The effects of the environment on migration have been studied less than those of migrants on the environment but are also becoming of increasing interest (Kane, 1995; Myers, 1997). Throughout human history, first hunter-gatherers and then shifting cultivators have customarily moved once they depleted their natural supply of food or the fertility of the soil in their area of cultivation (Davis, 1974). Although this custom of mobility in response to humanly-induced environmental degradation still exists among small populations of hunter-gatherers and shifting cultivators, from the Kung Bushmen of the Kalahari Desert in southern Africa to the Yanomani, Huitoto, Huaorani, and many other ethnic groups of the Amazon basin and southeast Asia, the populations involved are small. Today, interest in environmentally-induced migration has focused on the issue of "environmental refugees"[21], that is, *international* migrants compelled by environmental conditions to seek temporary asylum in another (usually neighboring) country; on "displaced persons", who are people forced to migrate within their country by environmental disasters; and on other persons who migrate from rural areas within their own country *at least partly* for reasons of environmental deterioration. The latter, not commonly referred to as environmental refugees except in the sensationalistic literature, is by far the most numerous, but because of the general neglect of the international funding community on *internal* migration in low-income countries and because it does not usually involve persons in desperate need of assistance, it has received very little attention.

[21] According to the 1951 Geneva Convention, refugees are persons outside their country of citizenship who are unwilling or unable to return to their country because of a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion.

There are two kinds of factors that may cause such deterioration of the environment as to impel people to leave: (1) a major natural disaster (earthquake, flood, volcanic eruption, hurricane, etc.), or (2) a gradual, cumulative deterioration in the productivity or livability of a place. Most of the time, major natural disasters produce *internally* displaced persons, but sometimes--because of the magnitude of the disaster, the poverty of the country and its inability to provide assistance, and its closeness to an international border--people cross that border seeking refuge and are accepted as international refugees.

Regarding the possible effects of *cumulative* processes of environmental degradation on internal migration in developing countries, the Dominican Republic provides an interesting case study (Zweifler, Gold, and Thomas, 1994). A time series of air photographs was linked to survey data to examine the processes influencing land use change in a hill community called Las Ayumas. Settled around 1900, Las Ayumas was a vibrant albeit poor frontier community until 1940, with rice, plantains, maize, beans, and other crops raised in food gardens known as *conucos*. But as early as the 1940s, settlers had cleared most of the original forest and soil fertility began to decline. Farmers responded first by reducing the cultivation of nutrient-demanding crops such as peanuts, tobacco and rice, and switching to less demanding perennials such as pasture and coffee. The village also became more incorporated into the market economy, which spurred crop intensification. A boom in world coffee prices led to an expansion of the land area in coffee to 40 per cent by 1959, at which time, forests still covered 23 per cent of the land area. This fell to 7 per cent by 1968, during which time the main local urban center, Santiago, also grew rapidly, attracting young adult male labor away from the village. This led to even greater dependence on land uses that demanded low labor inputs as well as being tolerant of depleted soils, such as coffee and pasture, once again. From 1968 to 1983 the area in coffee further expanded, reaching 63 per cent of total land use, while food gardens shrank. Cassava, bananas and sweet potatoes, crops that can tolerate degraded soils, also replaced the earlier basic foods grown in *conucos*. Thus over the past 50 years, the decline in soil fertility led to both out-migration as well as changes in land use in favor of crops with lower demands on labor and soil nutrients.

It is likely that similar processes of adaptation, including out-migration, have been occurring and continue to occur widely in the developing world even though the underlying, long-term process of environmental degradation (e.g., declining soil fertility) is rarely ferreted out in survey questionnaires. For example, in both Brazil and Ecuador, major waves of migrants to the Amazon originated in areas characterized by recurrent droughts (from Northeast Brazil and the southern Ecuadorian Sierra province of Loja), which may be related to deforestation, desiccation and declining availability of water, and nutrient-depleting agricultural practices in areas of origin (as well as periodic climatic droughts). In Guatemala the virtually complete deforestation of the Altiplano led to high soil erosion, which must have reduced soil fertility (Leonard, 1987). While nutrients can be restored to soils through fertilizer, the loss of soil itself cannot be compensated except over millennia. Since most farmers in developing countries cannot afford the cost of

fertilizers to replenish nutrients, populations will tend to continue to migrate away from areas where soil fertility is depleted.

Although sudden environmental disasters or cumulative degradation is reported as important in the internal displacement of an estimated current stock of 6.5 million displaced persons, the precise role of environmental factors is hard to establish, especially where political, civil, religious or ethnic conflicts also play important roles (Lonergan, 1998). Lonergan describes (see also Black, 1999) with acuity how many studies have greatly exaggerated both the numbers of persons affected and the purported role of environmental factors as "the root cause" of both international migration in general and of refugee movements in particular, as well as of internally displaced persons. This was done perhaps to promote the wider acceptance and use of the concept of "environmental refugees," as well as to stimulate funding. Some of these studies even report numbers higher than the *total* numbers of refugees and displaced persons. As Lonergan notes, while there is indeed growing interest in studying the specific role of environmental factors in generating both international and internal migration, there is very little direct empirical evidence available. Nevertheless, a number of works touch on the topic, as is reviewed in the paragraphs below.

The relevance of poverty and inequality in access to resources and their use as well as to out-migration decisions is well-known. It is therefore crucial to disentangle the relationships between the environment, migration and poverty, especially in places known as environmental "hot spots", or where populations are highly vulnerable. The latter applies especially to the many countries that already have large numbers of internally displaced persons--including Afghanistan, Iran, Pakistan, Cambodia, Indonesia (of recent vintage), Angola, Rwanda, Burundi, Mozambique, Somalia, the Sudan, Democratic Rep. of the Congo, Ethiopia, Eritrea, Guatemala, and Mexico. Vulnerable populations also exist where severe rural poverty, agricultural neglect and declining soil fertility are evident—which applies to even more low-income countries and regions within countries, and to most indigenous populations and many minority groups, such as in the Amazon region, southeast Asia, etc..

Some of the recent studies reporting on the relevance of environmental factors in stimulating *international* migration include several on West Africa by Findley and colleagues. For example, Findley et al (1988) found that emigration from the Senegal River Valley of Mali, Senegal and Mauritania to France has increased in the latter half of the twentieth century and appeared to be linked to increasing drought.

With respect to *internal migration* in developing countries , numerous examples exist which suggest links to environmental degradation, although the evidence is mostly circumstantial rather than solid quantitative evidence that takes into account the various possible factors at play. Countries mentioned in this context in the popular and semi-scientific press include Bangladesh, Ethiopia, Kenya, El Salvador, Haiti, Mexico, the Sudan, Mali and other countries in the Sahel

belt, but in each case a number of other social, economic and political factors were also at play. Efforts to disentangle environmental factors from these other factors have been scant and largely unsuccessful. Relevant research includes Sambrook (1992) on the Dominican Republic; studies on Sub-Saharan Africa, including Randall (1998), Hamid (1996), Findley (1994), Findley and Diallo (1993), and Ruppert (1991) on the Sahel belt countries; Oyaya (1998) on Kenya; and several studies on Asia, including Jafri (1996), Gulati and Chopra (1994), and Kayastha and Yadava (1985) on India, and Nabi (1992) on Bangladesh.

In the Dominican Republic, Sambrook (1992) used data from a census and a survey of 450 rural households in the central highlands to examine the relationships between population pressure and environmental degradation at both the level of the farm and the lowest political level called the *sector*. At the sector level, higher density was directly linked to out-migration, while at the farm level, land degradation and out-migration of farmers appeared to be related. However, the linkages between population density per ha, intensity of land use, and out-migration were not consistently observed.

Among the studies on the Sahel, Randall (1998) used data from the 1976 and 1987 population censuses of Mali to document a decline in the nomadic population from 426,000 to 317,000 as a result of droughts which made it impossible for some to sustain their pastoralist way of life based upon moving seasonally with their animal herds. On the other hand, in a longitudinal survey of 309 households in 1982 and 1989 in Mali, Findley (1994) and Findley and Diallo (1993) found that out-migration did *not* rise as a result of the 1983-85 drought, and that instead circular migration increased, especially of women and children and mainly to towns. In the Sudan, Hamid (1996), based on a survey of 465 households, tribal leaders and others, saw displacement as resulting from famine, which was in turn ultimately due to droughts and desiccation (see also Ibrahim and Ruppert and Bilsborrow and DeLargy, discussed in section 4 above). Similarly, Ruppert (1991) found government projects which opened up new sources of water significantly affected (in-) migration in the rural Sudan. Ibrahim and Ruppert (1991) found the Berti of the large northern semi-arid Darfur province migrate away whenever rainfall and therefore carrying capacity of the land are limited. Finally, Oyaya (1998) found out-migration rose among the Maasai of Kenya during periods of drought.

In Asia, most studies on the topic have been on the Indian subcontinent. Jafri (1996) used data from a large study based on a sample of 844 households in 75 villages in Uttarakhand district in the Himalayas of Uttar Pradesh in northern India in 1985-86 to show that deforestation resulted in increased water runoff and soil erosion and also appeared to force out-migration, especially of males. This then led to abandonment of farms, higher female agricultural work and lower land productivity, and an overall decline in the cropped area in 1951-81. In another study, on 89 districts in semi-arid zones of western and central India, Gulati and Chopra (1994) report that population growth led to intensification of agriculture and over-grazing, which in turn led to environmental degradation, especially of common property areas. This ultimately led to out-

migration. In the Ghaghara floodplain of India, annual floods also forced out-migration, though most is temporary labor migration (Kayastha and Yadava, 1985). In Sri Lanka, high population density and declining farm sizes and productivity of lands leads to out-migration, though the specific environmental aspects are not addressed (Vandsemb, 1995). On Bangladesh, Nabi (1992) used a multiple regression analysis of data from the 1974 and 1981 population censuses to find that out-migration was associated with greater population density and prevalence of tenant farmers. The latter two factors were interpreted as reflecting land pressure , but evidently are not direct indicators of environmental degradation.

A study supported by the National Heritage Institute (1997) on the relevance of environmental factors in international migration from Mexico to the United States found only weak relationships but did not use good indicators of environmental factors.[22] Lonergan concludes that "the key factor is that certain populations are becoming more vulnerable to environmental change because of other factors, primarily poverty and resource inequality..." (p. 11). This may indicate that interactions of environmental degradation and poverty are particularly important in inducing out-migration, and/or that poverty is much more important.

In general, despite the growing interest in the topic and increasing number of studies that deal with environmental impacts on migration decisions, the quality of research is weak, surely weaker than that on the effects of migration on the rural environment, reviewed in section 4 earlier. Moreover, despite growing interest in the topic of environmental refugees , studies examining the linkages between environmental conditions and *international* (out-) migration are even fewer than those that investigate environmental impacts on internal migration movements in developing countries.

6. Summary and Policy Implications

In this monograph I have noted that (according to the latest UN projections) rural populations will continue to grow for several decades more in most of Africa and much of Asia, even as they decline in Latin America. In addition, internal migration movements, notably rural-rural migration, are likely to continue to play prominent roles in population dynamics and environmental change in much of the developing world, including in Latin America. These two factors ensure that rural population dynamics will continue to be a potentially important factor in environmental change. After a review of theoretical perspectives dating back to Malthus, I then reviewed much of the recent published literature dealing with population and the environment in the Third World, on both the effects of demographic processes on the environment and the effects of environmental change on migration (mainly of environmental degradation on out-

[22]The statistical results on the determinants of (out-)migration from Mexico certainly do not support the statement (NHI, p. 5) that our findings demonstrate a strong correlation between land resource degradation....and migration both within Mexico and across the U.S. border . In any case, the same report calls for more in-depth research of the correlations.... , but research is needed using methodologies that go much further than correlations .

migration). Below I briefly review the findings from this literature discussed and critiqued above, and deduce some provisional policy implications.

The literature is much richer on the effects of migration on the environment than the converse, providing numerous examples in which the migration of farmers to the agricultural frontier has resulted in tropical deforestation or the desiccation of land in dryland areas (section 4 above). This has been a growing area of scholarly research, and is related to the concern of the international community about tropical deforestation and its implications for global warming and loss of biodiversity. The case studies surveyed above also indicate the crucial roles that natural resource endowments, local/community and national institutions and policy, and (in some cases) international markets and cultural factors have played in determining the manner and extent to which migration that extends the agricultural frontier has resulted in environmental degradation (as well as economic success or failure for the migrants themselves, which is also of considerable importance since most are poor). Thus, for example, road building and expansion has played a major role in opening up vast areas for exploitation and despoliation in various Amazon-basin countries, in Central America, in Thailand and elsewhere. This road building has usually been initiated by extractive (lumber, mining, petroleum) enterprises, usually foreign but with the explicit approval of the national government. Government policies to promote cattle ranching or the expansion of cash crops for export (usually by large landholders) have been key factors in Brazil, Honduras, Panama, the Philippines, Kenya, etc. And the lack of environmental policies or of their enforcement has played an important role everywhere.

Nevertheless, the *specific* roles of the many factors at the household, local community, and national levels have barely been touched upon in empirical research, in terms of either inducing (out-) migration from places of origin or on environmental degradation in places of destination. Among the factors that have occasionally been explicitly examined in empirical research and found relevant to either or both of the above, or which theory suggests may be relevant, are: (a) demographic factors at the household level (e.g., family size or composition) and community level (viz., population density, previous migration and migration networks); (b) socio-economic factors at the household level (such as education, employment experience, migration origin, land plot size and quality of soil) and community level (e.g., presence of markets, location relative to major cities, international borders; transportation infrastructure and linkages; rules governing access to land and natural resources; availability of schools, health and family planning facilities; employment structure and opportunities, wage and income levels; availability of credit and technical assistance; and social mores and cultural practices and beliefs); and (c) natural resource endowments (land availability, including forests and unowned or common property lands; quality of land; availability of water; topography, altitude and temperature; risk of area to flooding, drought or other natural disaster). Most of the household and community factors listed are in turn influenced by national policies and institutions (such as regarding land tenure and distribution; security; credit; agricultural development programs and technical assistance; lumber and mining concessions; fiscal policy and subsidies; export-import promotional policies,

including tariffs and quotas. Ultimately, the effects of such policies are filtered through local governments and institutions in terms of their potential effects on household decision making processes. It is a formidable task indeed to trace through and quantify these many complex and hierarchical linkages, but software has advanced faster than relevant attempts at applying it, again, due partly to the lack of attention of research funding agencies to migration. Perhaps this will change as it comes to be recognized that some of the most salient population-environment linkages are via migration.

Despite the limitations of present research findings, policy decisions need to be made *now*, by both governments and NGOs in developing countries and international agencies. Existing studies do indicate numerous instances in which migration to the agricultural frontier is playing a major role in tropical deforestation, the desiccation of landscapes, and land degradation. Given that many of the areas being settled are characterized by extraordinary biodiversity and that, for example, tropical forests also play crucial roles in world climate patterns and reducing global warming, it is in the interest of the international community to address the root causes of the migration that leads to this deforestation *as well as* how to reduce it *in situ*, at the frontier. Dealing with these issues involves a full range of interlinked population, development and environmental policy considerations that go beyond the scope of this paper, and which will vary from country to country. Nevertheless, some broad implications can be derived from the theoretical approaches and case studies here.

For this it is important to first distinguish policies relating to origin areas from those pertaining to the populations in the areas of destination. We take it as a given that the goal is, to the extent possible, to both improve livelihoods and reduce negative environmental impacts. If we are concerned about the effects of migrants extensifying agriculture, expanding the agricultural frontier, on the environment in areas of *destination*, we must grapple with what the factors are that stimulate them to leave their areas of *origin*. Policy measures relevant in (rural) areas of origin thus may include improving access to agricultural land, technical assistance, and inputs (especially water, such as through irrigation, and fertilizer) that facilitate the intensification of land use and increase yields, which reduces pressures to out-migrate. The most important factor is likely access to land, but international funding agencies and political leaders in developing countries (given the vested interests of the latter in most cases) bend over backwards to avoid confronting the issue of extreme inequality in landholdings and hence the need for *major* (not token, or paper) land redistribution or at least land taxes to ensure idle land is used (see Bilsborrow and Stupp, 1997, on Guatemala), which at least would generate employment. Many studies have shown a concentrated land distribution is directly linked to rural poverty, and poverty to out-migration. Other pertinent policies include improving the provision of socio-economic infrastructure, transportation and communications linkages, and especially economic production and employment opportunities in areas that people are migrating from, or improving them in alternative destinations. These are tall orders, and go to the heart of development policies generally, which have been characterized by urban bias in developing countries

(Lipton, 1977). However, a better term may be rural neglect, which could be addressed by a national policy of redirecting some resources from improving conditions in urban areas to improving them in rural areas, especially in areas of high out-migration to the agricultural frontier. However, in countries where the origin environment is degraded and population density high, out-migration is still likely, to unused lands if any remain or to urban areas, although policy changes could reduce it.

Government efforts to directly settle migrants, whether motivated primarily to reduce population density and lack of land access in areas of origin (e.g., Indonesia) or to exploit untapped resources in destination areas (Brazil and elsewhere in Latin America), have generally not been successful (Oberai, 1988). One reason is the nature of migration itself, and the dominant role of networks. Thus in both Indonesia and Brazil the number of sponsored migrants was soon overwhelmed by much larger numbers of spontaneous migrants,[23] attracted by word of mouth via migrant networks as well as by the roads built to provide access for the sponsored migrants. As a result, the environmental consequences of the original directed migrant settlement policies became much more negative than expected. A policy implication of this is that governments need not allocated substantial resources to recruiting the initial settlers, that in countries with great inequality in landholdings and access and high rural poverty, just providing access to land through roads will be sufficient to attract migrants.

In regions of destination, policies need to be developed to improve livelihoods of the mostly poor migrants. But such policies should take into account the desirability of protecting areas of particular ecological value while at the same time encouraging land use practices that are more sustainable and appropriate for the climate and soils than has been the case to date. Since high natural increase among migrant populations already settled in frontier areas is also in general adding substantially to demographic pressures on the environment,[24] improving access to family planning is important in these areas. These frontier areas have been neglected by both government agencies and private sector non-governmental organizations even as they facilitate such services in other parts of the country. Policies to encourage less extensive (less clearing of pristine areas) and more intensive land use practices are also desirable, and include those discussed above with respect to intensification in places of origin as well as additional policies more pertinent to areas of destination. The latter include (in tropical forest environments) promotion of agro-forestry, native species and nitrogen-fixing plants, and credit (for intensification, not for cattle purchase or pasture expansion, which provides little employment

[23]Bilsborrow, based on World Bank and other sources, found spontaneous migrants to be at least double the number of sponsored migrants in the Indonesia transmigration program (Bilsborrow, 1992).

[24] Fertility levels of populations along the agricultural frontier are generally quite high. An important exception is Brazil where total fertility levels on most of the Amazonian frontier are between 3 and 4 births per woman in her lifetime.

and is extremely demanding of space). Programs to pay farmers for preserving forests on their plots—for (preserving) the environmental services of the forest—have been tried with success in Costa Rica and Brazil and proposed Ecuador and other countries. In addition, road building and extension must be carefully planned, recognizing that providing access is an *immediate* threat to ecosystems, and instead focus on rationalizing access to areas already degraded or opened up or where biodiversity is limited. This in turn requires more and better assessments of the ecological value of areas (and the desirability of protecting them) and of the soil quality of areas (and of their agricultural potential) *before* new roads are built, so that they can be directed into the latter areas.

In summary, since most migrants to the agricultural frontier are poor, the challenge is to find ways of combating rural poverty in areas of origin while at the same time promoting a more sustainable use of the rural environment in both areas of origin and areas of destination.

7. Gaps in Knowledge and Research Needs

The population and the environment field is becoming a new subfield within the field of demography. An important subfield is migration and the environment, which has attracted considerable attention from researchers in recent years, although hard evidence on the relationships is still very limited. In this review I have examined the state of this subfield based on the recent literature on population growth, migration and the rural environment, focusing on developing countries. This has involved looking at data on trends in rural population and migration to rural areas, examining briefly alternative theoretical perspectives, and assessing empirical evidence. It is evident that there are shortcomings in the data characterizing migration flows (e.g., failure to obtain rural and urban origins and destinations of migrants in census data), in the available theoretical paradigms, and especially in the quality of the empirical evidence purporting to link population/migration and the rural environment. The limitations in theory and evidence result from the complexity of the relationships—which involve causation in both directions and multiple dimensions or ways of appraising the linkages, reflecting the various disciplines that provide relevant knowledge; the fact that relationships vary from one context to another (see below); the different definitions, mechanisms and units of measurement used by the different investigators and disciplines (such as geographic units based on political/administrative definitions used by demographers and economists vs. ecosystems used by ecologists); and the lack of adequate empirical estimation methods. This has led to the resulting plethora of *ad hominem* assertions in both the popular and scientific literatures.

An area that has been hardly touched is the role of environmental factors on affecting (out-)migration movements from degraded areas, though such migration (both national and international) has occurred, and in many cases must be related to the effects of environmental degradation on reducing the productivity and livability of (origin) areas (see section 5 above). This is in turn directly related to the lack of data at the micro (household or community) level on

actual or perceived roles of environmental factors on (out-) migration decisions in the first place, and to the general neglect to undertake measurements of key, relevant environmental factors (such as soil quality, deforestation, desiccation of soils or declining access to water). Obtaining such environmental data at the micro level and linking it to survey data providing demographic and related information on resource users is needed to provide the data to distinguish environmental factors from other social, economic, demographic and larger community or policy factors in affecting migration decisions.

Given that institutional and policy factors play major roles in mediating the effects of population variables on the environment, another important issue is to improve the collection of data on those factors, develop better ways to use such data to formulate appropriate variables to capture their key aspects, and better model and estimate their effects on population-environment linkages. This requires far more attention to the collection of data at the community and larger levels, such as the district and state or province, and even the national and international level. Thus national and world prices of commodities extracted or grown in frontier agricultural environments—such as for tropical hardwoods, petroleum, coffee, beef (see Walker et al, 2000, on Brazil, cited in section 4 above), cacao, and even a crop usually grown for subsistence, casava (in Thailand—see section 4)—affect land use in frontier areas, as filtered through national and local policies. Better ways of modeling these processes are needed to better quantify the effects of policies, such as hierarchical multi-level models.

As population-environment linkages involve relating people to resources spatially, research has just begun to take advantage of the considerable potential offered by the use of remote sensing data. That is, both people and aspects of the environment may be geo-referenced, both on the ground using Global Positioning System (GPS) devices, and in space based on satellite observations from Landsat and other more precise imagery, such as Ikonos. The former permits examining people-environment linkages spatially, on the ground, far better than has been possible before, while the latter can provide measures of land cover and land use (and change over time) at a higher scale, such as for ecosystems, administrative areas or regions of a country (once the boundaries are geo-referenced). Classified satellite images also provide direct estimates of land use which can be compared with reports from land users on the ground, and possibly thereby provide more accurate measures of dependent variables when they are measures of land cover or land use.[25] A number of projects currently being funded by the U.S. National Aeronautics and Space Agency (NASA) are currently conducting studies that should substantially increase our knowledge of the potentials of this type of research, and, to the extent the technology is found useful, of actual population-environment linkages.

[25] Sader et al (1997) notes how satellite images reveal the ongoing deforestation in the Maya Biosphere Reserve in Guatemala. The Brazilian Government is working with Raytheon and IBM to use satellites to monitor illegal forest fires in the Amazon, and to catch and prosecute violators.

A problem in carrying out research in this area is the use of different units of observation by demographers and geographer-environmentalists, and therefore the difficulty of matching demographic-socio-economic data and environmental data. Thus the former collect data for individual persons, households, communities, regions or countries as delimited by administrative/national borders, while the latter are based on pixels of several square meters to 30 m on a side (Landsat). But the knowledge base is improving rapidly, providing better measures of environmental change, at various scales.

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