NEGLECTED DIMENSIONS OF GLOBAL LAND-USE CHANGE: REFLECTIONS AND DATA

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Foreword

This paper by Gerhard Heilig is an effort to transcend disciplinary boundaries in the study of global land-use change. With a multi-dimensional approach, he seeks to identify the most important underlying agents of change by going beyond the usual study of alternative agricultural practices. In addition to population growth, he singles out political decisions and changing lifestyles, i.e., tastes and habits with respect to food consumption, housing, clothing, transportation, smoking, etc., as major driving forces of land-use change.

The paper systematically uses the AGROSTAT databank of the FAO to provide an empirical foundation for these points. The work was clearly inspired by IIASA's interdisciplinary research setting. It also illustrates that by transcending the usual boundaries, one quickly enters scientific *terra incognita* for which structured analytical tools still need to be developed. This paper seems to make an important step in the right direction.

Wolfgang Lutz
Leader, Population Project

Neglected Dimensions of Global Land-Use Change: Reflections and Data

GERHARD K. HEILIG

READING PAPERS AND BOOKS on land-use change is a somewhat monotonous experience. The authors tend to address just two subjects: deforestation and land-cover change brought about by agricultural practices.[1] A typical recent example is a report of the Human Dimensions of Global Environmental Change Programme (HDP) published by the International Geosphere Biosphere Programme (IGBP) (Turner, Moss, and Skole 1993). While the authors of this report stress the need for analyzing the demographic, cultural, economic, and social causes of land-use change, they mostly describe trends in deforestation and agriculture. One chapter is titled "Underlying Human Driving Forces"—but it deals mainly with large-scale investments in agriculture. The prime illustrative case in the report is the deforestation of the Amazon Basin. No one would doubt that this region is affected by serious land-cover modification, but is change in the Amazon Basin triggered by local forces? Or, posing the question in a broader context, is the surface of the Earth really shaped by impoverished slash and burn farmers, agribusinesses, and logging companies?

This note questions the conventional approach in studying land-use changes in which agriculture-related alterations are viewed as driven by population growth. Numerous other types of land-cover modification occur, such as those caused by lifestyles, food preferences, manmade catastrophes, armed conflict, urban infrastructure expansion, industrial production, fossil resource exploration, and transportation. We can understand the underlying causes of global land-use change only if we widen our conceptual focus. Expansion and intensification of agriculture and livestock production affect large areas of the globe, but these processes are just the most visible outcome of more fundamental social, economic, and technological changes. Monitoring and describing global trends in deforestation and agricultural land-use change are important, but these processes cannot be understood unless we abandon the simplistic notion of a causal sequence from population growth to increased food demand to agricultural expansion and intensification to deforestation. Our physical environment is shaped primarily by other, less obvious mechanisms.

This note highlights aspects that are usually neglected in the debate on land-use change. I begin by drawing on "everyday knowledge" about different forms of land use to show the diversity of human activities that modify global land-use patterns. I then develop a conceptual framework that brings together seemingly unrelated processes and driving forces, with the intention of broadening the focus for future research on land-use change beyond the physical dimensions. I examine land-use data from 180 countries for the period 1961–63 to 1989–91 for possible interactions between population and land use. Finally, I discuss lifestyle factors that can trigger global land-use change.

The diversity of human land use

To get a fresh perspective on a scientific subject, it is often a good idea to start with a commonsense list of what we know about it—including matters that might have come to be ignored in the standard academic interpretation. Here is a quick inventory, along with illustrative examples, of types of human land use. Apart from agriculture and livestock production we use land for:

human habitation (housing stock in cities and villages)

manufacturing and industrial facilities (factories, car-testing sites)

the food supply infrastructure for consumers (stores, shopping centers)

the food supply infrastructure for wholesalers (commercial centers, trade fairs, marketing facilities)

the water and energy supply infrastructure (dams, pipelines, power plants, oil fields, coal mines, gas stations)

recreation and sport facilities (amusement centers, zoos, parks, gambling casinos, ski slopes, sports stadiums, golf courses, race tracks, swimming halls, ice skating rinks, hunting reserves)

tourist facilities (hotels, beaches, hiking trails)

waste deposition and sanitation facilities (landfills, sewage treatment plants, municipal and industrial waste deposit sites, slag heaps of coal mines)

education and training facilities (kindergartens, schools, university campuses)

military establishments (restricted areas, shooting ranges, military airports and harbors, training grounds, barracks) transport infrastructure (streets, highways, turnpikes, airports, car parks, railroads, harbors, pipelines)

health care infrastructure (hospitals, nursing homes)

storage facilities (oil and gas tanks, water reservoirs)

cultivation of plants for drugs (marijuana fields, coca fields, tobacco fields)

cultural and religious facilities (concert halls, museums, theaters, temples, churches, cemeteries)

bureaucratic facilities (office buildings, administrative and government structures)

communication facilities (telephone, television, radio).

This list illustrates the broad range of human activities that can trigger land-use change. But most of these activities are ignored in debates about land use, since their impact is thought to be negligible compared to changes caused by agricultural expansion and modernization. For example, the aforementioned IGBP/HDP report on land-use and land-cover change flatly states: "The two largest land uses, in terms of their spatial domain, are arable cultivation and livestock production" (Turner, Moss, and Skole 1993: 18). Indeed, the available statistics create the impression that global land-use change is mainly a matter of agriculture and forest exploitation. According to the authors, Table 1, reproduced from the IGBP report, shows that:

> Around 14–15 million km^2, an area about the size of South America, is in some form of cultivation. An additional 70 million km^2 is used for some form of livestock production, as either rangeland or pasture. In contrast, settlements of all kinds and their infrastructure (e.g., roads) cover only a few percent of

TABLE 1 Human-induced conversions in selected land covers

Land cover	Date	Area (in million km^2)	Date	Area (in million km^2	Percent change
Cropland[a]	1700	2.8	1980	15.0	436
	1700	3.0	1980	14.8	393
Irrigated cropland	1800	0.08	1989	2.0	2,400
Closed forest	Preagricultural	46.3	1983	39.3	–15.1
Forest and woodland	Preagricultural	61.5	1983	52.4	–14.8
Grassland/pasture[b]	1700	68.6	1980	67.9	–1
Drained land			1985	1.6	
Settlement					
Urban			1990	2.5[c]	
Rural			1990	2.1	

[a]Estimates given from two different sources. [b]Includes some areas often classified separately as shrub and arid land. [c]Includes substantial areas not built up.
SOURCE: Turner, Moss, and Skole 1993; based on Meyer and Turner 1992.

> the world's land area. Understanding global scale patterns in land-cover change therefore requires detailed investigation of the changes in the rural land use. (1993: 18)

Other authors, for example Meyer and Turner (1992), have come to similar conclusions. Grübler (1992: 1) asserts that "the area covered by artifacts of our technological civilization most likely cover less than one percent of the Earth's land area. In contrast, the areas used for agriculture and pasture cover close to 40 percent of the global land area."

Although these statistics are widely cited, suspicion about their pertinence is warranted. If one excludes areas that are for all practical purposes uninhabitable, such as the North Pole, Antarctica, high or very steep mountainous areas, or regions with very harsh climates (such as found in Northern Asia and North America), the proportion of land covered by human structures is in fact much higher—perhaps in the neighborhood of 7 percent. For instance, Grübler's data also show that in the Netherlands 6.3 percent of the land is devoted to parks and recreational areas, 10.5 percent to infrastructures, residential buildings, industry, and commerce, and 10.8 percent to other uses. In other words, some 28 percent of the country's land area is under some kind of human use other than agriculture or livestock production. Forests, on the other hand, cover just 9.7 percent of the land in Netherlands, and Dutch agriculture takes up only 22.6 percent.

But even if we were to assume that land use for human infrastructure is minor compared to agriculture-related land use, we should not be exclusively concerned with the latter. The fundamental global change currently underway is not primarily driven by the increasing food demand of a rapidly growing population or by the profit interest of agribusiness. To return to the example of the Amazon Basin, the process of deforestation in the region cannot be understood without taking into account the role of technology. The advanced construction machinery that was used to cut the Transamazonica Highway through the forest was a crucial ingredient of the process. Political influences were probably equally important. Brazil's leaders arguably triggered the widespread land-cover change when they decided to develop the country's vast interior areas (Mahar 1989). In 1960 the country's capital was moved to Brasilia, deep in Brazil's vast and then largely empty Savannah region, necessitating the construction of a network of roads and other infrastructure. This opened up a remote area for mass migration of the urban poor. The Brazilian military had its own special interests in making the northwestern parts of the country accessible. The familiar observation that farmers and logging companies are about to destroy one of the last large natural rain forests of the Earth reveals nothing about these motives and strategies, and about the underlying structural forces. Collecting ever more detailed inventories of land-cover change in the Amazon Basin (or anywhere else) does not help us to understand the fundamental human driving forces that cause land-use change.

Human driving forces: A conceptual framework

To understand the rapid changes affecting the Earth's surface on the eve of the twenty-first century we must take into account at least five basic trends. These are the rapid spread of the scientific–technological revolution; the historically unprecedented increase of population; the growing affluence in Europe, North America, and parts of Asia and Latin America; the worldwide changes in lifestyles, which are partly explained by rising per capita income; and the growing influence of geopolitical, economic, and military structures and strategies. These fundamental trends shape what might be called the proximate determinants of land-use change. They include the expansion of transportation networks and infrastructure; increases in spatial mobility and tourism; the expansion and modernization of agriculture and livestock production; and the growing demand for commercial energy and raw materials. These forces, in turn, are linked to certain alterations of the land surface and its biotic cover, notably deforestation; drainage of natural wetlands; regulation of river systems and creation of artificial lakes; man-induced desertification; chemical and nuclear contamination of water and soils; and sealing of land through artifacts (airfields, streets, buildings). In the end these land-cover modifications can change regional hydrology, reduce biodiversity, influence biogeochemical cycles (including the emission of radiative trace gases such as CO_2 and CH_4), and affect the climate at large. They can trigger soil erosion and increase sediment transport (Turner et al. 1990).

Everything else being equal, population growth evidently has an impact on global land use. More people require more food, more houses, more power generation, more roads and railways—more of everything. The critical phrase, however, is "everything else being equal," for things are not constant in human affairs. People have always tried to improve technology and adapt to changes in climate and population density. Migration has always been a mechanism for releasing the pressures of excess population or escaping from environmental disaster. Trade and cultural exchange between societies have long facilitated adaptation and change. The carrying capacity of the land is not a natural constant; it is a variable strongly influenced by human action (Heilig 1994). Studying the relationships between population growth and land use in isolation from these factors is a fruitless endeavor.

Today, the most powerful driving forces that modify the relationship between population and land are science and technology. They are changing the conditions of life even in the most remote parts of the world. Natives of arctic regions use automatic rifles to hunt; Chinese paddy rice farmers apply more nitrogenous fertilizers on average than their European colleagues; agricultural and land-use data in Egypt are collected for a Geographical Information System with the help of satellite navigation devices;[2] the oil-producing desert countries in West Asia have the highest density of desalination plants in the world; high-yield varieties of rice and corn are used in most of the modernized Asian agricultures; cars and motorbikes are ubiquitous (in Java people use the term "Honda revolution"); the direct-dial phone connection between Bali and Vienna is a matter of seconds; and so on.

The spread of the scientific–technological revolution from North America, Europe, and Japan to most of the third world has triggered a fundamental change in agricultural productivity. Most Asian countries, including China, India, and Indonesia, have doubled or tripled food production in the past 20 years. This "green revolution" has established a new balance of people and land. Technological change is also the key in the rapid expansion of transportation and communication networks. That expansion not only encourages mass tourism and migration, it also contributes to the spread of Western values and lifestyles to many parts of the world. The material aspirations of an Indonesian farming family that twice a week watches a television show from the United States or Germany in which people drive around in Mercedes or Chevrolets are quite unlike those of an earlier generation. The global trend toward using motorbikes and automobiles is one of the most powerful forces generating land-use change.

As new technologies emerge and better ways of production are implemented, people become wealthier and change their consumption patterns. For instance, a global trend toward greater consumption of animal-based foods is occurring even as people in parts of Europe and North America are tending to reduce meat consumption. In China, meat consumption has increased very rapidly over the last two decades, requiring expansion of livestock production in large parts of Asia.

The increase of spatial mobility and changes in lifestyles will result in significant increases in energy consumption even if mitigating technologies and energy-saving measures are vigorously implemented. The third world, and especially Asia, its most populous component, is eager to follow the already affluent societies: creating more dams for hydropower generation, expanding networks of energy distribution, constructing more oil and gas pipelines, developing road networks. All this will contribute to changing the land cover of the Earth.

Data on land-use change

Statistics from the AGROSTAT databank of the Food and Agriculture Organization shed light on the human driving forces of land-use change. Because the data are derived from official government reports, they are accompanied by the usual caveat that "definitions used by reporting countries vary considerably and items classified under the same category often relate to greatly differing kinds of land" (Food and Agriculture Organization 1991: ix). But while methodological problems of FAO's land-use data might restrict their use in detailed quantitative studies, they are adequate to convey the overall picture.

Global trends

Worldwide, "forest and woodland" and "other land" account for about 31 and 32 percent of the land area. Thirty-seven percent is classified as agricultural area, of which only 10 percent is arable land; most of the rest (26 percent) is used as permanent pastures. Less than 1 percent of the land area is covered by permanent crops; only 1.8 percent is irrigated. Between 1961–63 and 1989–91 forests declined by about 8 percent. This decline—amounting to some 345 million hectares—was mainly due to an increase (by 210 million hectares) of permanent pastures and, to a much lesser extent, to the expansion (by about 88 million hectares) of arable land. The area of permanent crop production increased only moderately (by 18 million hectares), but that increase was significant in relative terms (a 24 percent gain). Irrigated agriculture expanded significantly, both in absolute and relative terms: by some 98 million hectares—that is, by 69 percent (see Figure 1).

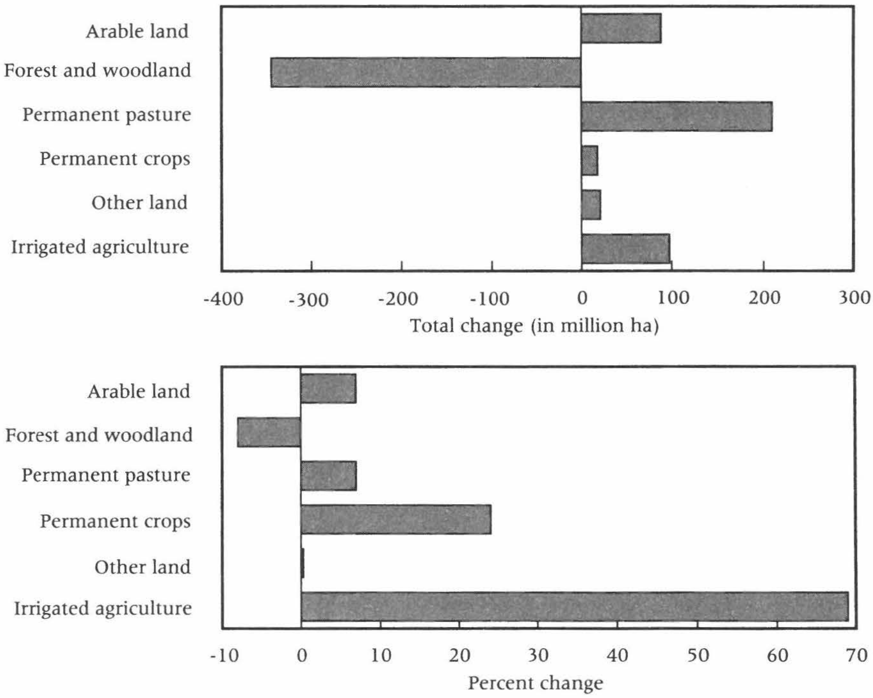
Regional trends

Trends in land-use patterns over the period 1961–63 to 1989–91 differed markedly by region (see Figure 2). While arable land expanded in Latin America, Africa, Oceania, the Far East, North America, and the Near East, it shrank in Europe and the former Soviet Union.[3] In Europe explicit policies have been formulated to foster the transformation of cropland and pastures into "natural" land. Between 1988 and 1991 alone, countries of the European Community withdrew nearly 1 million hectares from agricultural production. In East Germany about 13 percent of arable land was taken out of production in 1990–91 (Bundesministerium für Raumordnung 1991: 63).

Regional patterns of change affecting forest and woodland were similar. Such lands declined in Latin America, Africa, the Far East, Oceania, the Near East, and—if the statistics are correct—in the former Soviet Union; such lands increased in North America and Europe.

Contrary to the worldwide trend, permanent pastures declined in North America, Oceania, Africa, Europe, and other more developed countries, while they significantly increased in the Far East, Latin America, the former Soviet Union, and the Near East.

FIGURE 1 Global changes in land use and land cover by main type of land use between 1961/63 and 1989/91



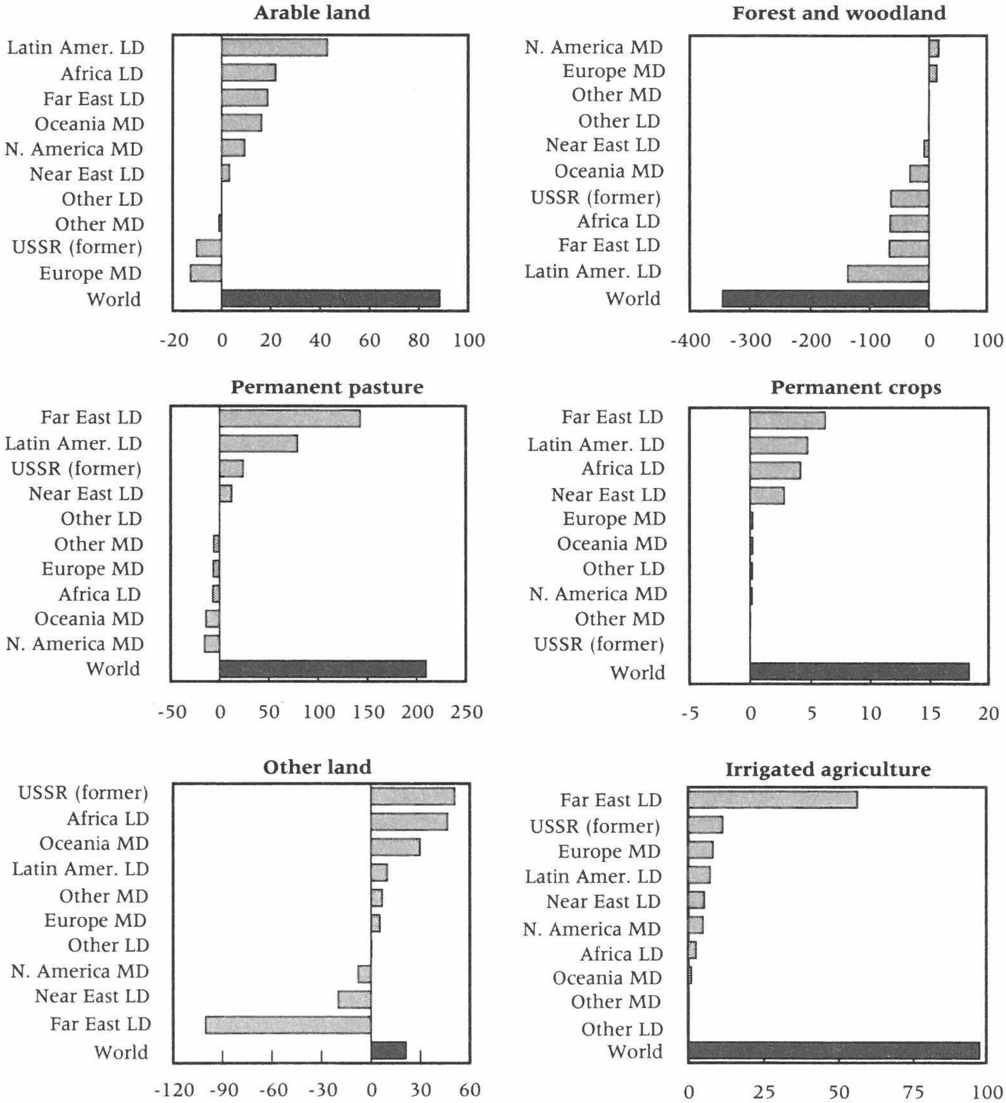
SOURCE: FAO 1994.

Trends in changes of "other land" (which includes barren land, built-up areas, roads, etc.) were also extremely divergent. For purposes of comparison I calculated the percentage population growth between 1962 and 1990 for each of the regions. Such growth was generally much higher than the changes within each of the land categories. While the population of sub-Saharan Africa's developing countries grew by 124 percent, their arable land expanded by just 20 percent and their forests and woodlands shrank by about 9 percent.

Country trends in land use

Thirty countries reported changes in arable land of more than 1 million hectares between 1961–63 and 1989–91. They are shown in Figure 3. Among these countries, Brazil, Australia, India, Thailand, the United States, and Argentina reported the largest increases; China reported the largest decline. The size of forest and woodland changed by more than 1 million hectares since 1961–63 in 56 countries (see Figure 4); in all other countries for which

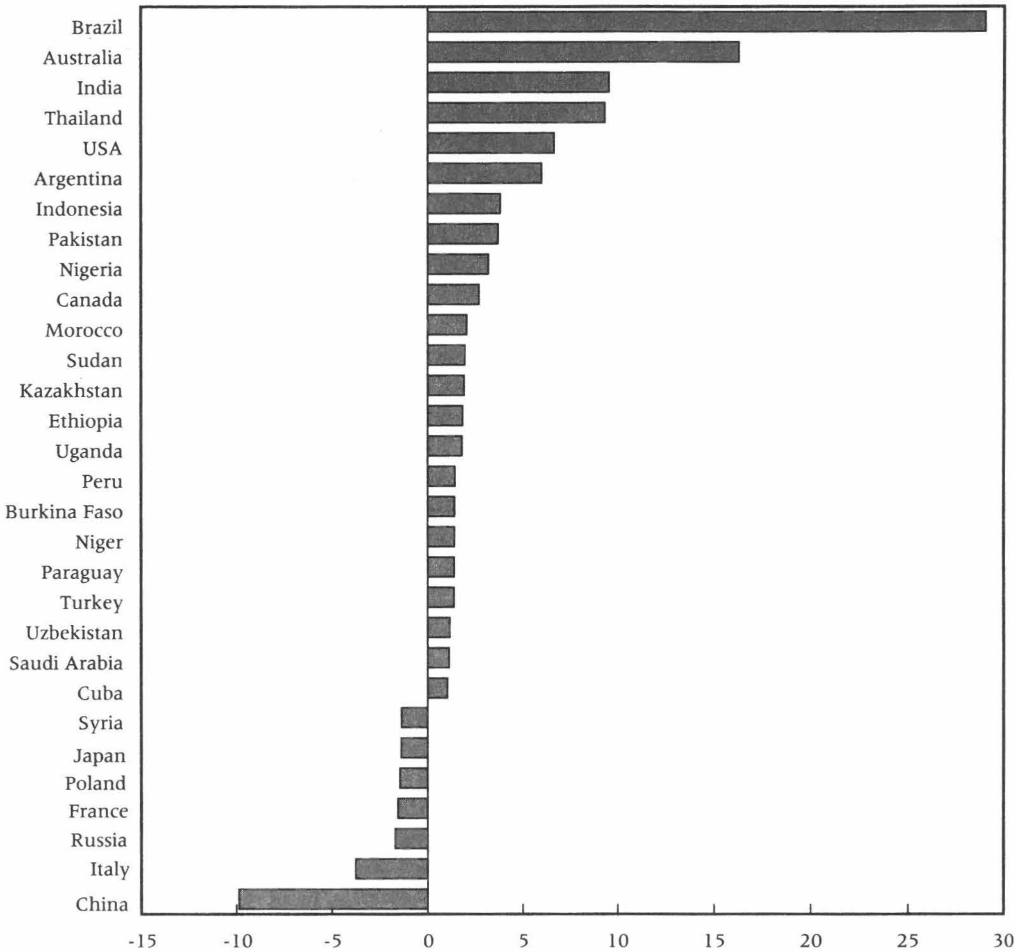
FIGURE 2 Changes in land use and land cover by main type, by world region between 1961/63 and 1989/91 (in million ha)



NOTE: LD = less developed (or developing); MD = more developed (or developed); see also note 3.
SOURCE: FAO 1994.

we have data, the change was minor. Canada and India reported the largest increases of forest and woodland; Brazil, Australia, China, the United States, Mexico, Indonesia, and Thailand reported the largest declines. Among the 180 countries that reported changes of permanent pasture, 28 had

FIGURE 3 Largest changes in arable land by country between 1961/63 and 1989/91 (in million ha)

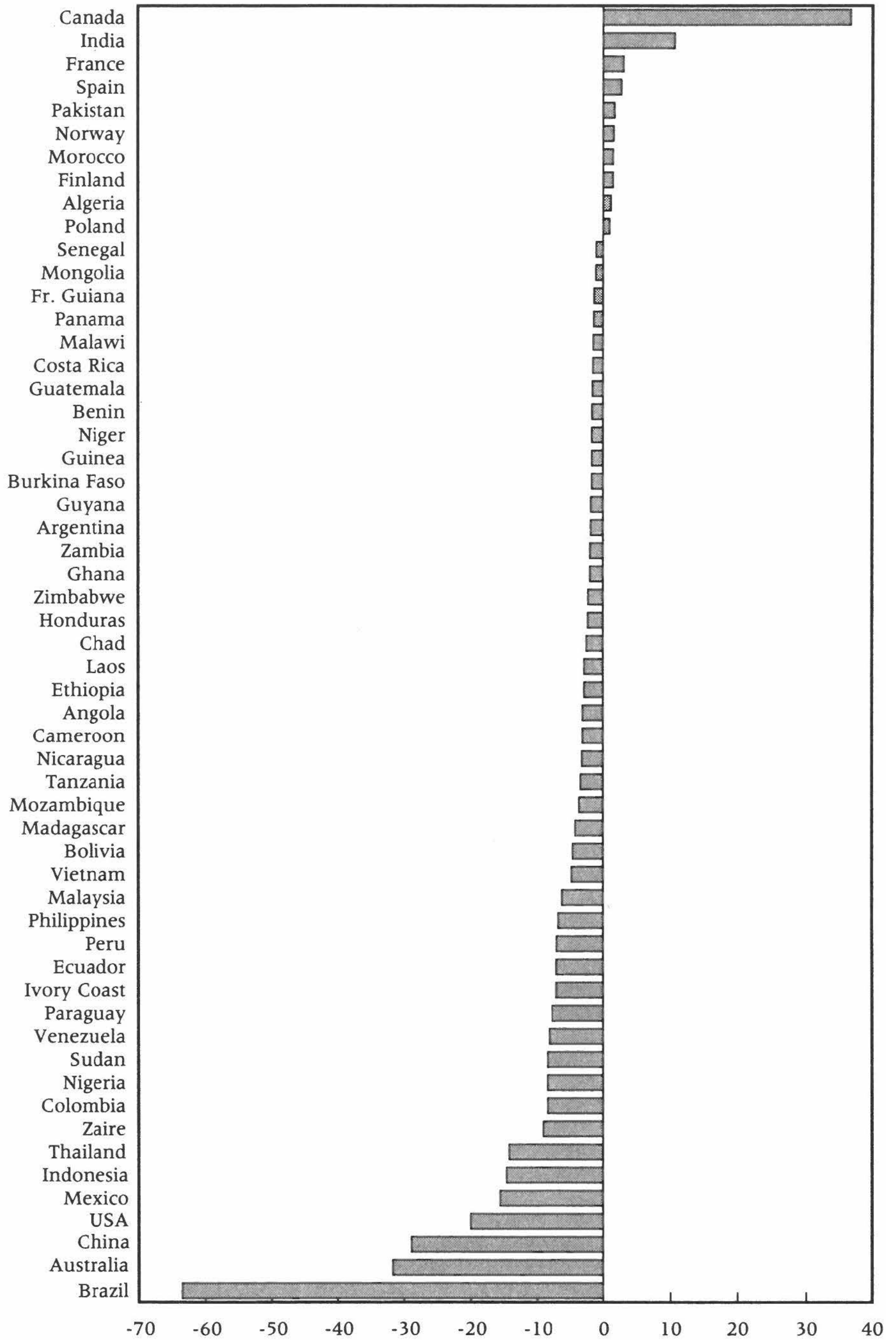


NOTE: Countries in which change exceeds 1 million hectares.
SOURCE: FAO 1994.

changes of more than 1 million hectares (see Figure 5). China and Brazil stand out with the largest increases; the largest declines were reported in the United States, Mongolia, and Australia. Worldwide, only Thailand, Brazil, Philippines, China, and Indonesia reported increases in permanent crop area of more than 1 million hectares; India reported the only major decline (see Figure 6).

In 14 countries the increase in the area of irrigated agriculture was more than 1 million hectares (see Figure 7); in no country was a decline of that magnitude reported.

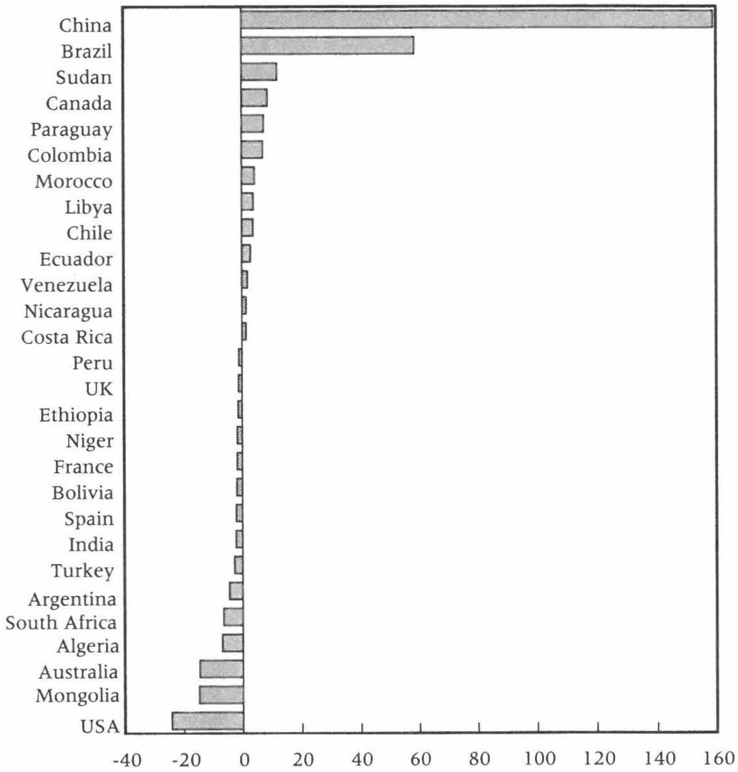
FIGURE 4 Largest changes in forest and woodland by country between 1961/63 and 1989/91 (in million ha)



NOTE: Countries in which change exceeds 1 million hectares.

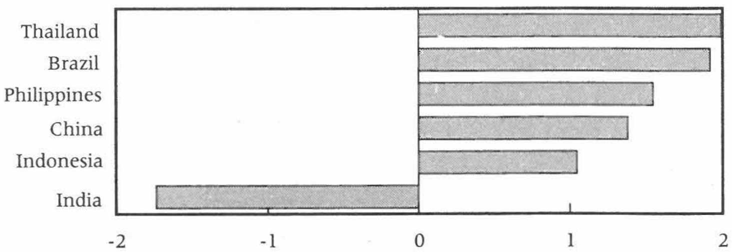
SOURCE: FAO 1994.

FIGURE 5 Largest changes in permanent pasture by country between 1961/63 and 1989/91 (in million ha)



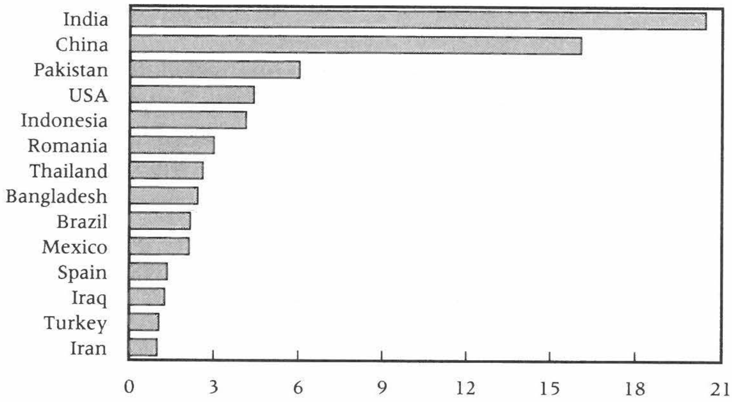
NOTE: Countries in which change exceeds 1 million hectares.
SOURCE: FAO 1994.

FIGURE 6 Largest changes in permanent crops by country between 1961/63 and 1989/91 (in million ha)



NOTE: Countries in which change exceeds 1 million hectares.
SOURCE: FAO 1994.

FIGURE 7 Largest changes in irrigated agriculture by country between 1961/63 and 1989/91 (in million ha)



NOTE: Countries in which change exceeds 1 million hectares.
SOURCE: FAO 1994

Intensification of land use

Measured by FAO's broad categories, surprisingly little agricultural land-use change took place during the period 1961–63 to 1989–91. A closer look, however, reveals marked changes in methods of cultivation. Global consumption of nitrogenous fertilizers increased sixfold during the period, from 13.2 to 77.2 million metric tons; and the number of agricultural tractors grew from 15.4 million (in 1967–69) to 26.4 million. This growth of agricultural inputs was not caused by an expansion of agriculture, but by intensification. Per hectare of arable land the consumption of nitrogenous fertilizers increased from 10 kg (in 1961–63) to 57 kg (in 1989–91) (see Table 2). Tractors in use increased from 12 per 1,000 hectares of arable land (in 1967–69) to 20 (in 1989–91). Population density increased at a much lower rate—from 2.5 to 3.9 persons per hectare of arable land. Massive land-use changes were also indicated by a significant increase of irriga-

TABLE 2 Fertilizer consumption and agricultural tractors in use, 1961/63–1989/91

Years	Arable land (in million ha)	Nitrogenous fertilizer consumption (million metric tons)	Agricultural tractors in use (millions)	Population (millions)	Nitrogenous fertilizer consumption (kg per ha arable land)	Tractors in use (per 1,000 ha of arable land)	Population density (persons per ha of arable land)
1961/63	1,259	13.2	–	3,136	10	–	2.5
1967/69	1,282	26.3	15.4	3,550	20	12	2.8
1989/91	1,347	77.2	26.4	5,297	57	19	3.9

SOURCE: FAO 1994.

tion: between 1961–63 and 1989–91 the area of irrigated agriculture was expanded from 140 to 238 million hectares. This agricultural intensification improved land productivity: worldwide, average cereal yields increased from 1.4 to 2.7 tons per hectare of area harvested.

The exploitation of forest lands has also intensified. Between 1961 and 1990 production of roundwood increased from 2.1 to 3.5 billion cubic meters. Worldwide exports of roundwood in the three-year period 1961–63 were 43 million cubic meters; by 1989–91 exports had nearly tripled, reaching a volume of 125 million cubic meters. This 191 percent increase in the worldwide roundwood trade cannot be explained by the 69 percent population growth alone. Increasing wealth and changes in lifestyles triggered this intensified exploitation of forests and woodlands.

Similar trends of intensification can be observed in livestock production. Between 1961–63 and 1989–91 the worldwide stock of pigs more than doubled, from 426 to 856 million heads; the number of ducks increased from 234 to 548 million. According to FAO, the number of chickens worldwide nearly tripled, from 4.0 billion to 10.6 billion between 1961–63 and 1989–91. This increase of livestock outpaced population growth almost everywhere in the world. For instance, population in the Far East grew by 80 percent between 1961–63 and 1989–91, whereas the stocks of chickens, ducks, and pigs increased by 278, 147, and 248 percent, respectively (see Table 3). Worldwide, the stock of cattle increased at a much lower rate than the population. However, this is just the number of heads—nothing is said about their productivity, how the cattle are fed or kept. A much better indicator of livestock-related land-use changes is the amount of slaughtered meat. It increased tremendously between 1961/63 and 1989/91—especially in Asia. The production of slaughtered meat in the Far East was some 8 million tons in the early 1960s; today it is 46 million tons, which is more than the total slaughtered meat production of Europe. This 470 percent increase was almost six times higher than the 80 percent growth of the population in this region. Hence, we should have an important geographical shift in livestock-related land-use patterns between Europe, America, and Asia.

The rapid expansion of livestock affected land-use patterns in three ways: the increase in demand for feed crops triggered further expansion of feed-crop areas and/or intensification of production;[4] in some parts of the world permanent pastures expanded; and the rising amounts of animal manure led to groundwater pollution and soil degradation in some areas of high livestock concentration, such as the Netherlands.

Population growth and land-use change

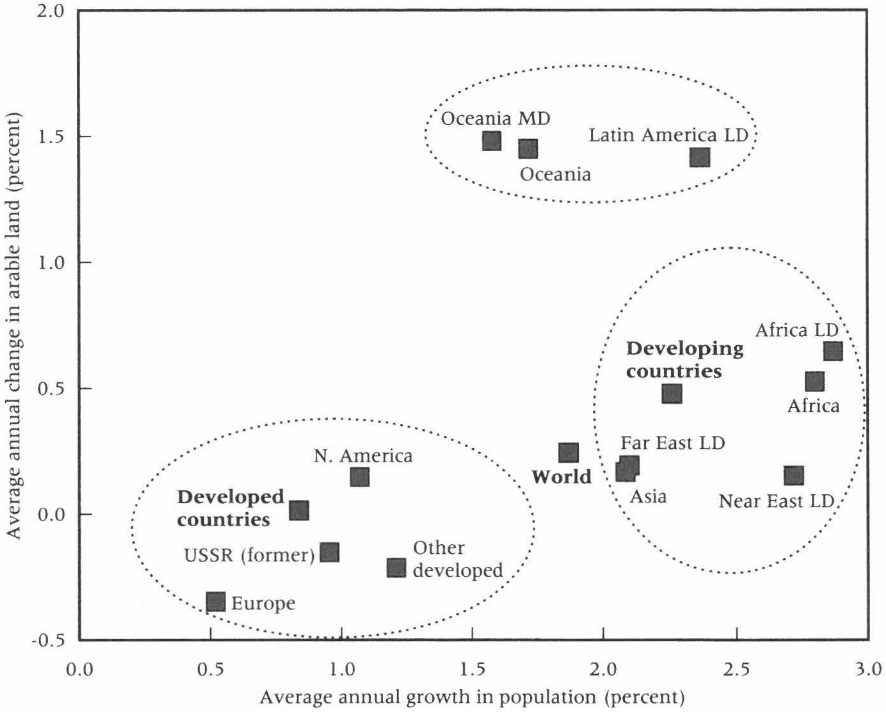
Population growth is often investigated as one of the major driving forces of global land-use change (see Rudel 1989; Bilsborrow and Okoth-Ogendo 1992). Larger populations, ceteris paribus, need more roads, vehicles, houses,

TABLE 3 Changes in livestock production and in population by major world region, 1961/63–1989/91

Region	Cattle 1961–63 (million heads)	Cattle 1989–91 (million heads)	Cattle Change 1961/63–1989/91 (percent)	Chickens 1961–63 (million heads)	Chickens 1989–91 (million heads)	Chickens Change 1961/63–1989/91 (percent)	Ducks 1961–63 (million heads)	Ducks 1989–91 (million heads)	Ducks Change 1961/63–1989–91 (percent)	Pigs 1961–63 (million heads)	Pigs 1989–91 (million heads)	Pigs Change 1961/63–1989/91 (percent)	Population 1961–63 (millions)	Population 1989–91 (millions)	Population Change 1961/63–1989/91 (percent)
More developed															
North America	113.0	110.8	–2	838.7	1,440.0	72	4.0	7.0	75	65.2	65.1	0	205.1	276.8	35
Europe	117.4	123.1	5	889.0	1,253.3	41	25.0	35.7	43	110.6	182.9	65	433.0	500.8	16
Oceania	24.5	31.1	27	24.7	63.3	157	—	—	—	2.3	3.0	33	13.2	20.5	55
USSR (former)	81.6	117.9	44	483.0	1,158.0	140	—	—	—	65.1	77.5	19	221.6	289.5	31
Other developed	16.2	18.0	12	117.7	395.3	236	—	—	—	5.0	13.3	166	116.5	163.5	40
Less developed															
Africa	102.0	150.8	48	230.7	717.3	211	4.0	8.0	100	4.2	15.1	259	235.0	524.8	123
Latin America	178.5	322.1	81	363.7	1,272.7	250	6.3	18.3	189	51.4	76.7	49	230.8	448.0	94
Near East	34.0	48.6	43	111.0	632.3	470	4.0	10.0	150	0.12	0.44	268	130.8	280.3	114
Far East	288.9	359.0	24	972.0	3,671.7	278	190.0	468.7	147	120.8	420.0	248	1,546.9	2,786.5	80
Other developing	0.33	0.58	77	2.0	8.0	300	—	—	—	0.84	1.63	94	3.34	6.33	90
World	956.4	1,282.0	34	4,032.3	10,613.3	163	233.7	548.3	135	425.5	855.6	101	3,136.4	5,927.0	69

NOTE: On the classification of various regions see note 3.
SOURCE: FAO 1994

FIGURE 8 Change in arable land by population growth: World regions, 1961/63–1989/91



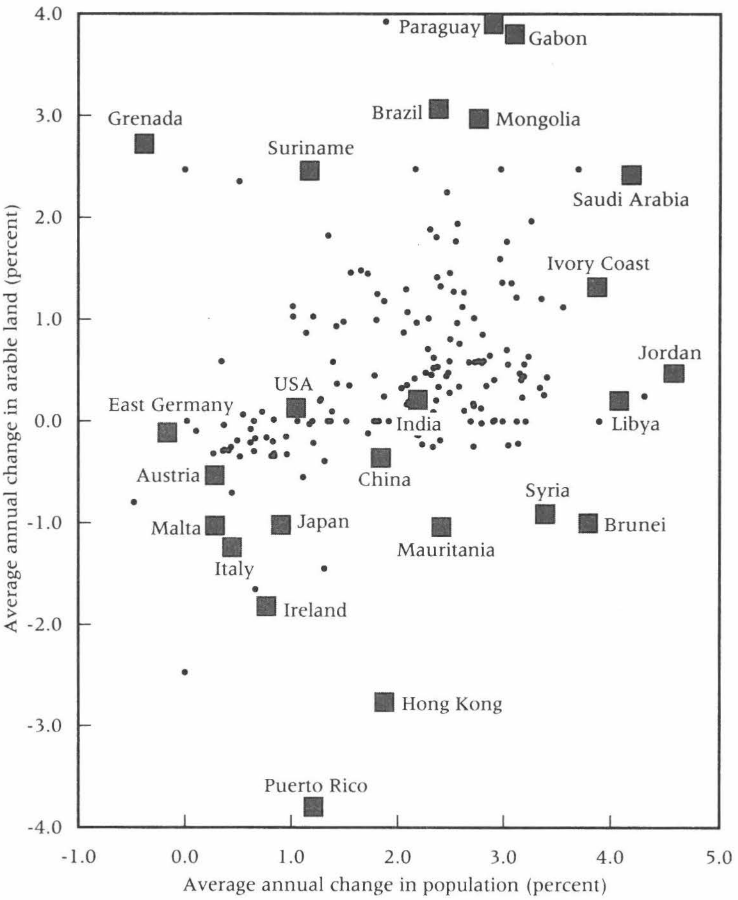
NOTE: LD=less developed (or developing); MD=more developed (or developed); see also note 3.
SOURCE: FAO 1994.

communication structures; and they use more water, energy, and food. However, the association between people and land is not simple, because it does not operate in isolation. Demographic effects can be aggravated or dampened by the effects of other forces driving global land-use change, such as technological innovation, change of lifestyles, or political decisions.

Figures 8 to 13 show changes in population size and density and in GNP per capita by changes in the size of arable land, forest and woodlands, and irrigated agriculture.[5] We can find scant first-order correlation between demographic variables and FAO's land-use categories.[6] The only exception is a correlation between population growth and change of arable land. Individual country data confirm this assertion. For instance, contrary to expectation, one finds instances of rapid deforestation in countries with relatively low population growth, and substantial forest expansion in countries with high population growth.

Australia, for example, experienced one of the most rapid declines of forest and woodland in the 1970s (a shrinkage of 23 percent between 1971

FIGURE 9 Change in arable land by population growth or decline: 180 countries (selectively identified), 1961/63–1989/91

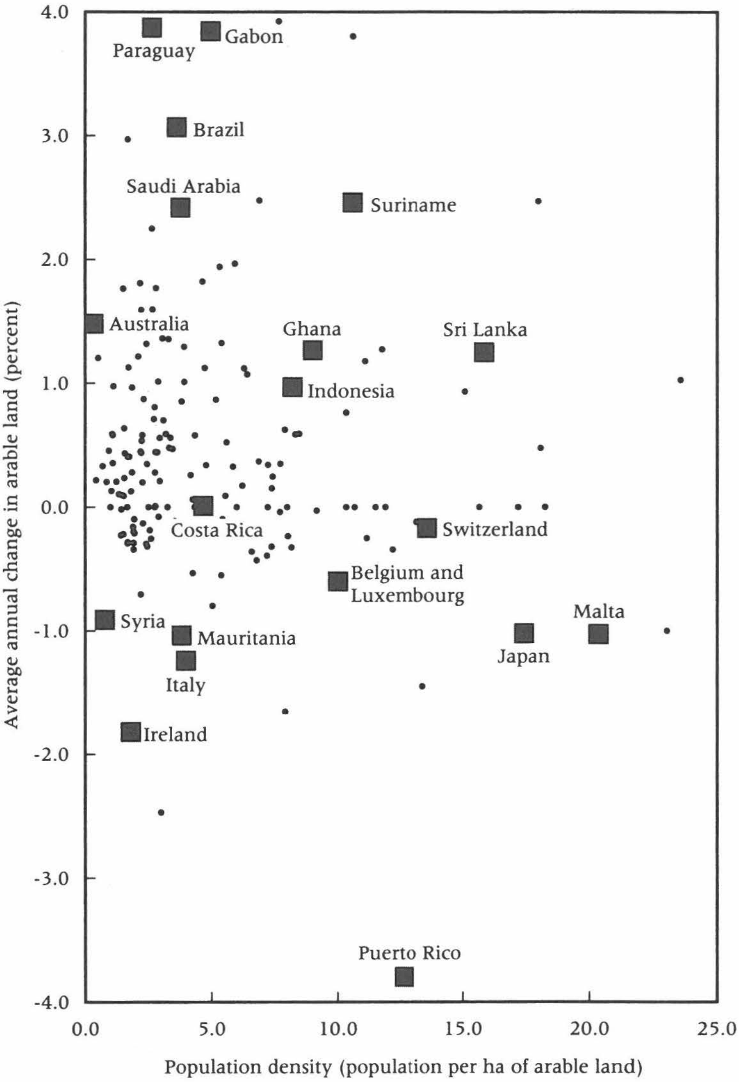


SOURCE: FAO 1994.

and 1980) yet the country's population growth was only moderate—12 percent for the decade. Arable land increased during that decade by just 7 percent. In contrast, Brazil showed one of the highest increases of arable land (42 percent) during the 1970s. Yet the forest area declined only moderately, by 3.9 percent. Even more surprising is the case of Algeria: this country experienced very high population increase (32 percent) during the 1970s and one of the largest increases in forest and woodland.

Admittedly, this lack of correlation in our country-by-country analyses does not prove that there is independence between population and land-use change. Flaws in the FAO data might explain some of the results, and

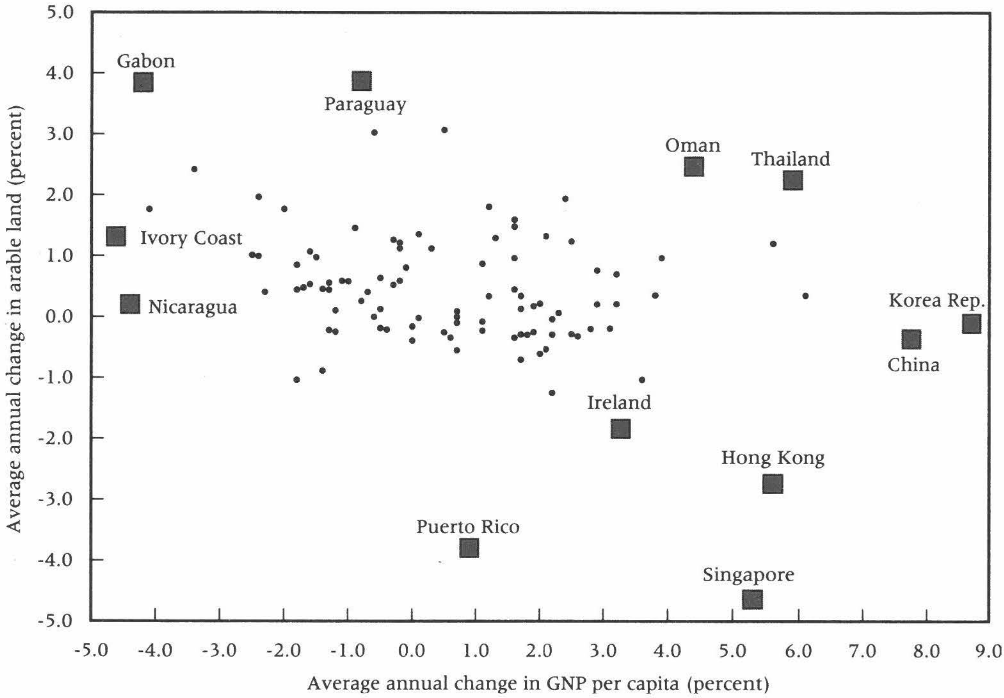
FIGURE 10 Change in arable land, 1961/63–1989/91, by population density in 1961/63: 165 countries (selectively identified)



SOURCE: FAO 1994.

we might find correlation if we chose other indicators of land use. It is also possible that aggregation of data on the country level conceals divergent within-country trends. Overall, however, the data support the claim that other variables fundamentally modify the interaction between population and land use.[7]

FIGURE 11 Change in arable land, 1961/63–1989/91, by change in GNP per capita, 1980–91: 93 countries (selectively identified)



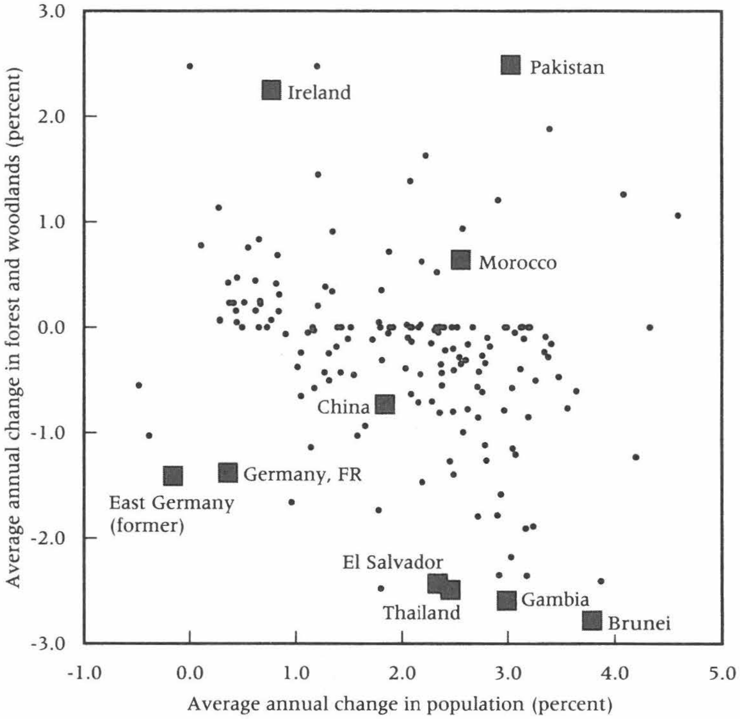
SOURCES: FAO 1994; World Bank 1993.

The effect of transportation and communication infrastructure

As noted above, the conversion of natural land into land occupied by manmade structures and by transportation and communication facilities accounts for only a small fraction of worldwide land-cover change. Although accurate statistics are not available, it has been estimated that all such conversions, including buildings and streets in urban areas, cover less than one percent of the Earth's surface (Grübler 1992: 1). Yet, I claim, it is precisely this kind of land use that is of paramount importance for the alteration of the globe's surface.

Consider the potential effects on a remote forest area of a newly built small road. The influx of loggers, oil explorers, poor farmers, merchants, land speculators, prostitutes, and tourists could change the land within a few years. Thus the construction of the road—a small intervention with minor direct loss of natural vegetation and animal life—can result in alterations many times the multiple of the original impact (Lay 1992).

FIGURE 12 Change in forests and woodlands by population growth or decline: 167 countries (selectively identified), 1961/63–1989/91

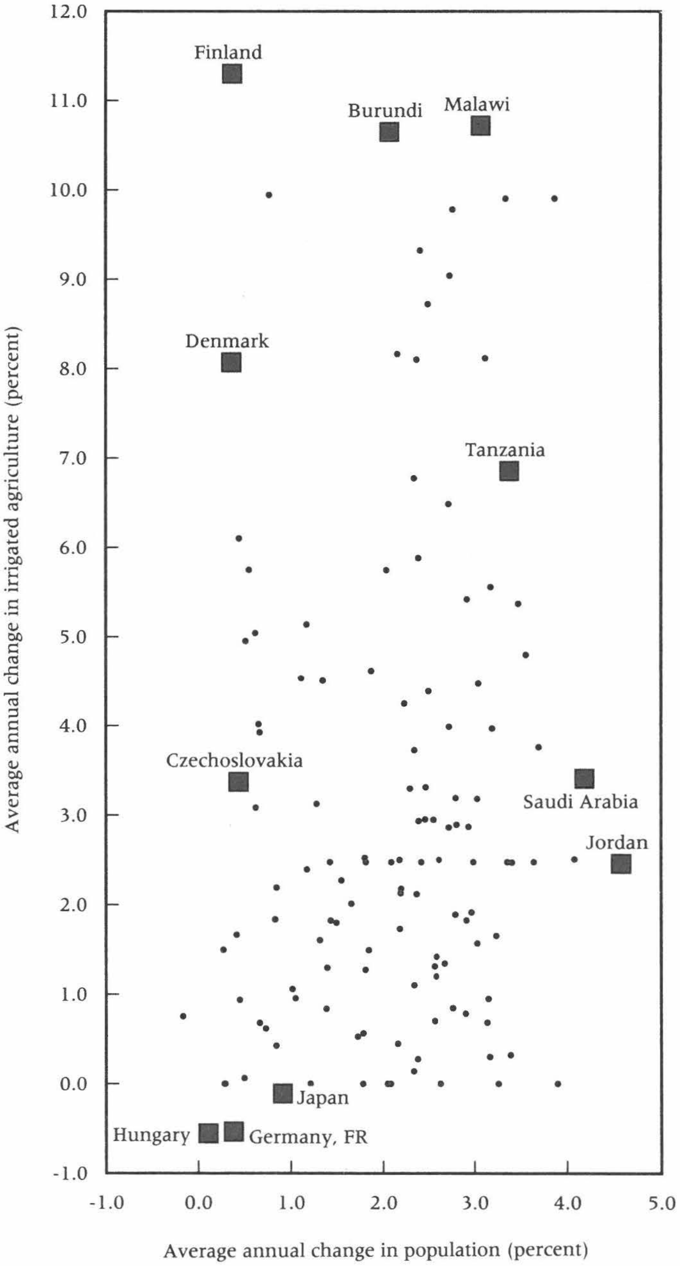


SOURCE: FAO 1994.

Railroads were probably the single most important manmade structures causing land-use changes in the last 150 years. Since February 1804, when Richard Trevithick first put a steam engine on iron rails to drag five wagons from Pen-Y-Darran to Abercynon in Wales, this technical wonder has changed the world. Railroads opened up the North American continent, and they made it possible to efficiently exploit the European colonies in Africa and Asia. Railroads built by the English colonists are still the backbone of India's transportation system. And the Dutch-built railroad from Jakarta to Bandung and Surabaya made Java's interior highland accessible, triggering large-scale conversion of natural land into plantations.

It is interesting to note in this context that very often the original motive for building transportation and communication infrastructure is unrelated to the subsequent land development. Military considerations, for instance, frequently play a crucial role in opening up remote areas. The knowledge that adequate transportation infrastructure is essential for a rapid deployment of troops is as old as war itself. The Roman and the Napoleonic

FIGURE 13 Change in irrigated agriculture by population growth or decline: 127 countries (selectively identified), 1961/63–1989/91



SOURCE: FAO 1994.

Empires could dominate huge areas only because they devoted great resources to the construction and maintenance of road systems, which then stimulated the development of peripheral regions. Twentieth-century examples are numerous. Modern governments wanting to control separatist movements or guerilla activities developed road systems in the forests of northern Guatemala, northwestern Thailand, and Nicaragua. The Nazi government constructed the network of Autobahns to facilitate access to Germany's remote regions in anticipation of war. Likewise, construction by the Czarist government of the Trans-Siberian Railway, connecting the west and the far east of Russia, was driven by military considerations. Private profit is also a strong motive for building transportation and communication infrastructure. During the colonial era many parts of the third world were opened up for private or semiprivate exploitation through development of such infrastructure, which in turn triggered further colonization. Railroad systems in Africa and India are good examples.

Lifestyles and land-use change

Many languages have words and sayings that tell a story about the relationship between lifestyles and global land-use patterns. The "Silk road" refers to the ancient trading connection that opened up contacts between the Far East and Europe, and it is a reminder that clothing fashion has been a driving force of land-use change throughout history. The mulberry tree that feeds the silkworm came first from India to southern Europe at the time of Trajan (AD 52–117). It spread rapidly in the tenth century as Europe's noble classes came to favor silk dresses. The tree also spread to large areas in China where silkworm breeding flourished in the twelfth century—due in part to increasing demand from Europe. Even more instructive is the spread of the cotton plant. Until the modern era, clothing relied heavily on animal products—wool, skins, furs. Cotton became the cloth of the masses only during the seventeenth century in Southern France; eventually, huge areas worldwide were transformed into cotton plantations.

Changes in food preferences also have an important impact on global land-use patterns. Before 1450 the coffee bush was an unnoticed plant in Ethiopia. Historical documents show that people began to drink coffee during the fifteenth century in Aden and in Mecca. During the seventeenth century the habit spread to most of the Islamic world. Citizens of Venice had their first cup of coffee around 1615 and people of Paris first enjoyed this stimulant in 1643 (Braudel 1990). In 1991 coffee plantations worldwide took up some 11.2 million hectares (FAO 1994). Coffee is not the only stimulant that affected global land-use patterns. In 1610 a ship of the East India Company brought the first tea leaves to Amsterdam. The British—who became promotion agents for this Asian product during the following centuries—learned about the new fashion around 1657, when their coffee houses began to introduce the new drink (Braudel 1990: 264–265). In the eighteenth century tea became a product of mass consumption, changing the landscapes of Sri Lanka (formerly Ceylon) and northern India. Today, tea plantations cover some 2.5 million hectares worldwide (FAO 1994).

In many countries contemporary diets are quite different from diets just a few generations earlier. Chocolate, for instance, whether liquid or solid, was rare in Europe until the nineteenth century. In late eighteenth-century Paris only the noble class drank chocolate. There are no records on how much land was used in Mexico (from whence the product was imported) for growing cocoa beans at that time, but it was certainly not much. Today, some 5.4 million hectares worldwide are used to grow cocoa beans in order to satisfy the mass appetite for the host of products made from cocoa. Mass consumption of refined sugar is also a relatively modern phenomenon. Sugarcane was first cultivated in eighth-century China. Starting in the sixteenth century refined sugar was considered food in Europe; earlier it was used in small quantities as medicine. But sugar consumption began to boom only in the twentieth century. Between 1961 and 1990 the harvest area of sugarcane more than doubled. Today, an estimated 17.2 million hectares worldwide are used for growing sugarcane. I have already mentioned the worldwide trend to animal food. Especially in Asia, where many countries have a long vegetarian tradition, a fundamental shift in food preferences is occurring. For instance, in the Far East (which includes all developing countries of East and Southeast Asia) the production of slaughtered meat, hen eggs, and milk increased by 470, 436, and 172 percent, respectively, between 1961–63 and 1989–91 (while the population grew by 80 percent) (FAO 1994).

Changing food preferences continue to trigger widespread land-use change. Currently the demand for vegetable oils is booming (since dieticians have declared animal fats a risk to health). As a consequence the sunflower cultivation area more than doubled since 1961, from 6.7 to about 16.2 million hectares worldwide in 1989–91 (FAO 1994). Cultivation of other oil seeds is also expanding rapidly.

Many other fashions and habits affect global patterns of land use. Just a few centuries ago the noble elite in Europe began to enjoy a strange form of stimulation (which they learned from the "primitive" people in their colonies): they burned leaves rolled in thin paper and inhaled the smoke. In 1992 tobacco plants occupied some 4.8 million hectares worldwide. It is not known how much arable land farmers devote to the cultivation of coca, opium, and other drug plants. By some estimates in a number of countries such plants represent a major claim on arable land. Certainly, drug consumption has become a multi-billion-dollar business in northern America and Europe and has fundamentally affected land-use patterns in northern Thailand, Burma, Colombia, and a number of other countries.

More than 50 million hectares are used for the production of lifestyle-related products, such as stimulants, sugar, and tobacco (see Table 4). This is equivalent to some 4 percent of the world's arable land. If the area used for production of oilseeds (such as rapeseed and sunflower) is also included, close to 70 million hectares worldwide are taken up by lifestyle-related production. This estimate does not include lands devoted to the production of soya beans, a crop primarily used for feeding animals; a shift of diets involving heavy consumption of meat is a trend of the twentieth century. Altogether it is not unlikely that some 20 percent of arable land worldwide is cultivated for lifestyle-related products.

Mass tourism is yet another trend of modern societies that triggers widespread modification of the Earth's surface. The tourist industry strives to open up the last "untouched" areas of the globe to cater to the demand for leisure and excitement in affluent societies. A travel agency in Bavaria, for instance, organizes bus trips for elderly women across the Sahara or to Katmandu. This agency also organizes special bus trips to the reservation of Aborigines in the northwest of Australia's Outback. These buses, equipped

TABLE 4 Global changes in land use reflecting lifestyle-related demand and demand for nonfood agricultural products, 1961/63–1989/91

Product	Area harvested (1000 ha)		Percent growth 1961/63–1989/91	Area harvested (percent of total arable land)		Per capita production (kg)		Percent growth 1961/63–1989/91
	1961/63	1989/91		1961/63	1989/91	1961/63	1989/91	
Tobacco leaves	3,620	4,767	31.7	0.3	0.4	1.2	1.4	9
Hops	60	80	33.1	0.0	0.0	0.0	0.0	−11
Tea	1,333	2,454	84.1	0.1	0.2	0.3	0.5	51
Coffee	10,101	11,194	10.8	0.8	0.8	1.4	1.1	−19
Cocoa beans	4,157	5,430	30.6	0.3	0.4	0.4	0.5	22
Sugar beets	7,118	8,599	20.8	0.6	0.6	50.4	57.1	13
Sugarcane	8,993	17,220	91.5	0.7	1.3	140.9	198.2	41
Flax fiber	2,042	1,113	−45.5	0.2	0.1	0.2	0.1	−40
Hemp fiber	703	245	−65.1	0.1	0.0	0.1	0.0	−74
Jute, jute-like fibers	2,471	2,188	−11.4	0.2	0.2	1.0	0.7	−32
Linseed	7,842	3,924	−50.0	0.6	0.3	1.1	0.5	−54
Rapeseed	6,315	18,127	187.0	0.5	1.3	1.1	4.7	313
Sunflower seed	6,855	16,288	137.6	0.5	1.2	2.2	4.2	92
Seed cotton	32,351	33,447	3.4	2.6	2.5	9.4	10.3	10
Sesame seed	5,289	6,451	22.0	0.4	0.5	0.5	0.4	−12
Soybeans	23,998	56,150	134.0	1.9	4.2	8.7	20.1	130
Castor beans	1,287	1,600	24.4	0.1	0.1	0.2	0.2	16
Groundnuts	17,362	20,359	17.3	1.4	1.5	4.8	4.4	−7
Total	141,896	209,635	47.7	11.3	15.6	—	—	—

SOURCE: FAO 1994.

with air conditioning, cooking facilities, and sleeping trailer, can be encountered in the middle of African or Australian deserts, carrying an exhilarated group of elderly widows. Trekking tours in the Himalayas, photo safaris to Tsavo National Park in Kenya, or sightseeing tours to the Mayan temples in Tikal, can be booked in almost any travel agency in Europe. Thirty years ago Sulawesi—then Celebes—was a remote place where a handful of indigenous tribes lived in conditions untouched by the outside world. Since then, the Javanese settlers of the Indonesian government's "transmigrasi" program have greatly changed the land by steadily expanding their (quite infertile) fields into the island's rain forests. But the long-term impact on the island of the rapidly expanding adventure tourism may prove even more severe. Today, when the traditional villagers perform their colorful cremation ceremonies, often thousands of visitors line the dirt roads, and camera teams of European tourists crowd the procession.

Secondary land reclamation around newly developed tourist centers can be observed in many places, for example in Bali, Thailand, and the Maldives. Tourism can be a trigger for land-use change since it requires good infrastructure, which, once built, generates a variety of other economic activities.

Trendsetters of modern tourism are the youthful backpack globetrotters. It is hard to estimate their numbers, but by all evidence they are far from negligible. Exotic places in Latin America and in Thailand, Indonesia, India, and the Philippines attract thousands of young globetrotters from Europe and Northern America who would not consider themselves catalysts of global land-use change and indeed are rarely mentioned in statistics on tourism. Yet they are important as the explorers of our times, acting as the shock troops for mass tourism.

The myth of past harmony between population and land

Assessments of today's global changes in land-use patterns often bristle with words like "crisis," "destruction," "loss," and "breakdown." But the notion that today's changes are destroying a natural paradise in which humans once lived in harmony with nature and which our ancestors preserved through the centuries is largely an illusion. Much of human history, in fact, is a history of transformation—and, frequently ruthless exploitation and destruction—of natural resources. The garden landscape of England with its rolling meadows and pastures is not a product of unspoiled natural evolution but a result of the logging practices in the preindustrial era. For centuries England's forests were used for fuelwood or were transformed into the ships that made Britain great on the oceans of the world.

Of course, England was not the only nation that exploited its woodland for human use. During the reign of Louis XIV, "the Sun King," the forests of France were plundered to supply the wharfs and to produce charcoal for the emerging iron industry. Farmers cleared large areas of woodland for agriculture, reducing the forest area in France some 300 years ago to near its present size. Not coincidentally, between 1600 and the late eighteenth century the transport capacity of European merchandise fleets increased from some 600,000 tons to well above 3 million tons (Braudel 1990).

Similarly, the need for extending the food supply in former generations entailed major changes to the natural environment. During the Han Dynasty in the fourth and third centuries BC, the Chinese started to transform the natural landscape of eastern China into rice paddies. The ensuing process, which reached its climax during the eleventh and twelfth centuries, represents one of the earliest large-scale reclamation and irrigation schemes, scientifically planned and coordinated by the dynastic bureaucracy (Braudel 1990). The Mayan civilization provides another example of change brought by human intervention in nature. Scientists and historians have argued that the decline of the Mayan empire was largely the result of man-induced ecological degradation, resulting in deteriorating agricultural productivity.

Nor is war-induced environmental damage affecting land cover—exemplified by the application of defoliants in the Vietnam War—a new phenomenon. During the Thirty Years War (1618–48), Swedish troops cut down huge forest areas in Pomerania and sold the timber in order to fill their war chest (Lütge 1966: 335). Drifting sand replaced the forest, creating a peculiar landscape that can still be seen today.

Colonization of America not only caused the death of a large part of the indigenous population; it also triggered a near-eradication of many plant and animal species. The buffalo population, a mainstay of the Indians' food supply, was drastically reduced by the settlers—from an estimated 60 million in pre-Columbian times to fewer than 1,000 buffalo in 1895 (Thornton 1987: 52). The motive was not necessarily economic: early settlers frequently organized shooting parties, killing a few hundred buffalo as a sport.

Conclusion

Land-use change is a complex and diverse phenomenon. FAO AGROSTAT data show remarkable differences from region to region and from country to country and large variations of land-use practices within the same land-use category.

Actors that receive much attention in discussions of land-use change—slash and burn farmers, logging firms, and agribusinesses in the third world—are simply agents, and sometimes victims, of fundamental driving forces. These actors are driven by population pressure or respond to international markets that reflect changes in food preferences and lifestyles in the world's affluent societies. They use tools developed elsewhere, they are often supplied with capital from outside the country, and they frequently use infrastructure built for other (such as military) purposes.

The scientific–technological revolution, which is spreading even to the most remote areas, is a major driving force of global land-use change. It triggered the intensification of agricultural cultivation and the rise of international tourism and facilitated the spread of Western values and lifestyles.

The effects of population growth on land-use change can be understood, and should be studied, only in conjunction with these other driving forces, such as growth of income, changes in lifestyles, and political decisions. On a country-by-country level, one cannot find any direct correlation between population growth or density and land-use changes, as measured by the broad categories of FAO's land-use data.

A world population of 10 billion or more in the next century makes the continued modification of large surface areas of the globe inevitable. Population growth and improvements in living standards require more food, more housing, more space for human recreation. They also call for more space to be devoted to transportation infrastructure, resource exploration, and energy generation. Parallel to such expansion, however, technologies are being developed and utilized to save space, reduce pollution, and moderate harmful environmental impacts. We are forced to modify our physical world, but we can shape it for better or worse.

Notes

1 Among the countless publications adopting this approach see, for example, Houghton, Lefkowitz, and Skole 1991; Bartlett 1956; Allen and Barnes 1985; Bilsborrow and Okoth-Ogendo 1992; Brouwer, Thomas, and Chadwick 1991; Edwards et al. 1993; Malingreau and Tucker 1988; Richards 1990; and Barbier, Burgess, and Markandya 1991.

2 Personal communication with Roger C. Avery, International Health Institute, Brown University.

3 I use the economic classification adopted by the statistical system of the Food and Agriculture Organization, which has the following groups: Class I, Developed countries: Region A: North America, Region B: Europe, Region C: Oceania, Region D: Soviet Union (former), Region E: Other developed countries. Class II, Developing countries: Region A: Africa, Region B: Latin America, Region C: Near East, Region D: Far East, Region E: Other developing market economies. For details see FAO 1991: xvii–xviii. For convenience I refrain from mentioning the class category of the regions; thus Africa should be read as "Africa, developing" or Far East as "Far East, developing."

4 A good example is the enormous expansion in Brazil of the area sown in soybean, which is used primarily as a feed crop.

5 A number of studies have tried to quantitatively examine interdependencies of agricultural development, population growth, and land-use patterns with sophisticated statistical methods (e.g., Allen and Barnes 1985). The methodologically most advanced analysis is probably by Hayami and Ruttan (1985; the first edition of this book appeared in 1971).

6 I correlated a large number of demographic and economic variables, including

population size, population growth/decline, population density (by total land and arable land), GNP per capita, change of GNP per capita, and the Human Development Index with three land-use categories: size and change rates of arable land, of forest and woodland, and of irrigated agriculture. There was a significant correlation between population growth and the change of arable land, but only weak association between other demographic and land-use variables.

7 I am very skeptical about research that argues for an obvious correlation between population growth and land-use change. A typical example of a questionable correlation exercise of this sort is Allen and Barnes 1985, who write (p. 163): "Deforestation from 1968–78 in 39 countries in Africa, Latin America, and Asia is significantly related to the rate of population growth over the period and to wood fuels production and wood export in 1968; it is indirectly related to agricultural expansion and not related to the growth of per capita GNP." The authors conclude that "in the short term deforestation is due to population growth and agricultural expansion, aggravated over the long term by wood harvesting for fuel and export."

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