Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment

Edited by

D.R. Lee and C.B. Barrett

Department of Applied Economics and Management
Cornell University
Ithaca
New York
USA

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CABI Publishing
10 E 40th Street
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Tel: +1 212 481 7018
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3 Population, Agricultural Land Use and the Environment in Developing Countries

RICHARD E. BILSBOROW[1] AND DAVID L. CARR[2]

[1]*Carolina Population Center and* [2]*Department of Geography, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA*

Introduction

The earth's human population exceeded 1 billion for the first time in 1850. By 1999, the world's population reached 6 billion. The primary reason for such rapid growth during the past century and a half is that, despite the ongoing declines in mortality due to improved health conditions, fertility remained high for another generation or two in most countries (Teitelbaum, 1975). It is only since the 1970s that fertility has declined in most parts of the developing world.

In fact, the developing nations will be responsible for the entire increase of 2–4 billion persons that will be added to the global population during the next 50 years (based upon the United Nations (UN) medium fertility projections). This will increase their share of the global population from three-quarters to eight-ninths. Concomitantly, the loss of global forest cover is linked solely to deforestation in the developing world.[1] Once covering most of the earth, global forests have fallen to approximately a quarter of the terrestrial surface (FAO, 1995). If rates continue to accelerate as they did from 1984 to 1994 (by 40%), all primary tropical forests will be destroyed in another 50 years (Houghton, 1994).

Since sedentary agriculture dawned on the fertile banks of the Ganges, Tigris and Nile Rivers some 10,000 years ago (although recent evidence indicates that the first cultivated maize in central Mexico goes back nearly as far), growing populations have been fed by the expansion of agricultural land, mostly at the expense of forested areas. Despite technological advances and an increase in crop intensification, agricultural conversion was most dramatic during the 20th century. In 1900, 40 Mha of land were in crops around the world; by 1993, cropland had risen to 248 Mha (Brown, 1997). Resource degradation linked to rapid deforestation has led to chronic underdevelopment in rural areas

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where primary resource extraction is necessary for subsistence (Stonich, 1989; Dasgupta, 1995b).

Since the earth's land is finite, continued high rates of population growth in developing countries are thought by many to present urgent challenges to the sustainability of systems of food production and consumption (e.g. Meadows *et al.*, 1992; Pimentel, 1995; Brown, 1997). So far, with the exception of sub-Saharan Africa, agricultural production has outpaced population growth. However, global production has recently grown at a slower rate, the annual average rates of growth being 3.0, 2.3 and 2.0 in the 1960s, 1970s and 1980s, respectively (WRI, 1996). Further declines may be occurring in the 1990s (Brown, 1997).

The next section considers theoretical aspects of the relationship between trends in population, land use and agriculture; this is followed by an overview of the major world regions. Recent trends in the extensification and intensification of agriculture and population change will then be examined at the cross-country level for Latin America. This region is of particular interest since, during the first half of the 1990s, twice as much forestland was converted to agriculture there as in any other world region (World Bank, 1998b). A summary of some case studies illustrates the wide variability of relationships between population change and land-use change and the key roles played by contextual factors. Finally, we summarize and note gaps in knowledge and the need for more research at the micro or farm level.

Land-use Responses to Population: Some Theoretical Issues

Musing on human responses to population growth and land use has a long and diverse ancestry dating back to the Zoroastrians around 325 BC, the Indian sage Kautilya in 300 BC, the Bible, and Aristotle in his *Politics* (Petersen, 1972). However, the parson Thomas Malthus is credited with developing the first comprehensive theory of population–land use relationships. Malthus is most commonly attributed with having predicted that population growth would lead to famine and an eventual population crash, since, he noted, whereas human populations grow geometrically, food production tends to increase only arithmetically (Malthus, 1803).

But, in other passages rarely cited, Malthus also said that, since the most productive land tends to be used first, as population grows and the area used for agriculture expands with it, the average quality of new agricultural land brought into production declines, and thus mean land productivity also declines (Malthus, 1803). In addition, where land is fixed, classical economists noted that increased applications of labour lead to a fall in mean output per worker through the law of variable proportions, more commonly referred to as the law of diminishing returns (e.g. Ricardo, 1887).

Following more than a century of technological advances, including advances in agriculture that Malthus could not have foreseen, Boserup (1965) introduced the notion that technological change could mitigate the effect of population growth on food supply by facilitating increases in food production; that is, as available arable land becomes scarce relative to labour, societies adopt more labour-intensive techniques, which take advantage of increased labour–land factor ratios. Boserup enumerated five stages of land intensification through which agrarian societies evolve over time: (i) forest or long fallow (20–25 years between crops); (ii) bush fallow (6–10 years); (iii) short fallow (1–2 years); (iv) annual cropping; and (v) multiple cropping (more than one crop per year on the same land). These forms of increasingly intensive use of land embody increasing inputs of labour per unit of land per unit of time.[2]

Based on a review of historical processes in Japan and Europe, Davis (1963) proposed that demographic responses to population pressures on the land may occur: that is, rural populations may respond by reducing fertility through postponement of marriage and increased celibacy, increased regulation of fertility within marriage and/or increasing abortions. Davis considered out-migration as a last resort if these responses proved inadequate. He also proposed that the various responses may occur simultaneously (or 'multiphasically'), and that the more one response occurs – and the more the effects of population pressures on the land are thereby relieved – the less likely other responses are to occur.

In support of Davis's hypothesis, Friedlander (1969) found that fertility reduction preceded out-migration in preindustrial France. Scarce employment opportunities in French urban centres deterred rural–urban migration. With shrinking farmland per capita due to high fertility and the absence of out-migration possibilities, France thus became the first European nation to experience declining marital fertility, even prior to industrialization. According to Friedlander, fertility will decline to the extent that communities are constrained in relieving population pressures through out-migration.

However, studies of demographic responses (e.g. Davis, 1963; Friedlander, 1969; Mosher, 1980) neglect economic and land-use responses and vice versa. An attempt at synthesizing theoretical views is found in Bilsborrow (1987), who classified responses as economic (land intensification and extensification), demographic (fertility responses) and economic–demographic (out-migration). He hypothesizes that households traditionally exhaust economic options first, beginning with land expansion. If that is insufficient, then available land intensification technologies may be adopted, involving a decline in leisure time. If such adjustments together still prove inadequate, the next reaction is likely to be out-migration, temporary or seasonal migration at first, since that does not require giving up one's home and community. Permanent out-migration is likely to follow if prior adjustments, along with the remittances and savings brought by the temporary migrant, prove inadequate. This may take the form of either migration to urban areas, especially if wage levels are much higher there, or migration to other rural areas. The latter is more likely in countries with lands that have potential value for agriculture but are still unoccupied. This is particularly true of countries with significant endowments of tropical forests – for example, in South America and Central Africa. Finally, since customs producing high fertility are so deeply rooted in culture, fertility reduction is postulated to occur in traditional societies only as a *last* resort, when other adaptations have proved insufficient (see Bilsborrow and Geores (1992) for a more detailed discussion).

As illustrated in Fig. 3.1, these responses are mediated by factors operating at multiple scales within the physical and human environments (Bilsborrow, 1997). The following are some of the factors shown to influence household responses: (i) quantity and propinquity of potentially arable land (Boserup, 1965, 1981; Bilsborrow and Geores, 1994; Sambrook *et al.*, 1999); (ii) quality of natural resources, as manifest in climate, rainfall, topography and soil quality (Sanchez and Cochrane, 1980; Blaikie, 1987; Barbier, 1990; Buol, 1995); (iii) type of land tenure regime (Forster and Stanfield, 1993; Utting, 1993; Schmink, 1994); (iv) land distribution and the extent of landlessness (Stonich, 1989; World Bank, 1995a; Valenzuela de Pisano, 1996); (v) urban employment opportunities that may attract migrants (Stern, 1976; Alberts, 1977; Gilbert, 1994; Altamirano *et al.*, 1997); (vi) proximity and accessibility to product and labour markets (Rudel, 1983; Rudel and Richards, 1990); (vii) knowledge of and access to alternative forms of agricultural technology (Boserup, 1965; Zimmerer, 1993); and (viii) government policies, including those related to land distribution and tenure; tax and expenditure policies (including subsidies), especially those specifically encouraging extensification and intensification; transportation infrastructure (Bilsborrow, 1987; Hecht and Cockburn, 1990; Rudel and Richards, 1990); the fixing of prices for agricultural products (Garland Bedoya, 1991; Stewart, 1994); and family planning, education and health policies which affect fertility and mortality (Bilsborrow and Geores, 1992). With these

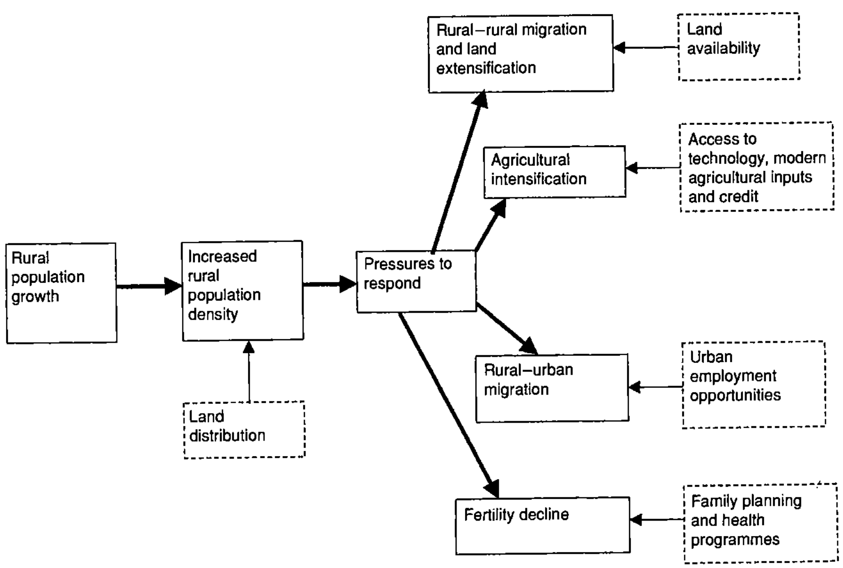

Fig. 3.1. Economic, demographic and economic–demographic responses to rural population growth.

conditioning mechanisms in mind, what does empirical evidence tell us about responses to population change among the major world regions?

A Glance at Global Relations

In an earlier paper, the first author looked at continent-wide relationships from a broad multiphasic perspective, based on estimates of trends over time (Bilsborrow, 1987). Data on demographic and economic changes in five developing country regions from the 1960s to 1980 were presented. Demographic change was measured by the change in the total fertility rate and economic–demographic change by the annual rate of out-migration from rural areas. Economic (or agricultural) changes comprised land extensification, measured by the percentage change in the share of arable and cropped land in total land, and land intensification, measured by the percentage change in rural labour productivity. The developing-country regions with the largest responses of one type did indeed tend to have smaller responses of the other types, as predicted by the multiphasic approach, and major deviations from the expected tradeoffs were generally explainable by exogenous factors, such as differences across regions in natural resource endowments or government policies.

Now that over a decade has passed, it is desirable to update that overview. We have prepared estimates of changes in the same four factors, up to and including 1995 (Table 3.1), revising the earlier period estimates using data sources appropriate for the latter period. The measures of all variables are the same as earlier, except that better estimates of rural out-migration have become available recently from the UN (1997). The caveats pertaining to the earlier study – especially the riskiness of cross-country comparisons, due to inconsistencies across countries and deficiencies in the underlying data – should still be kept in mind. We have presented data here for medians as well as for means, and we note where the means would be considerably different with the exclusion of outliers.[3]

Note that what we are concerned with here is the association between the change in rural population density and the associated demographic, economic–demographic and agricultural changes over two time periods. We observe at the outset that, at a continent-wide level, there was a slight increase in rural population density in Latin America in the first period (1965–1980) but none in the second (1981–1995), as fertility and natural population growth declined to equal out-migration from rural areas. In all other regions, however, rural population density rose substantially, most notably in China. In Africa, the Near East, China and especially 'Other Asia', the increase in rural density was much greater in the second period than in the first, implying that there should be greater responses.

Regarding economic or land-use responses, we expect agricultural land to increase where there is untapped land, which occurred in Latin America and 'Other Asia', as expected. Secondly, agricultural labour productivity rose substantially, except in sub-Saharan Africa, but this occurred more in the first time period (except for the Near East), probably due to the earlier exploitation

Table 3.1. Population density and economic, economic–demographic and demographic responses.

Regions	Economically active rural population/ A&P land[a] 1965–1966	1979–1980	1994–1995	Percentage change in arable and permanently cropped land 1966–1978	1979–1994	Percentage change in total fertility rate 1960–1965 to 1975–1980	1975–1980 to 1990–1995	Percentage change in rural labour productivity[b] 1966–1980	1980–1995	Rate of rural out-migration 1960s–1970s	1980s–1990s
Latin America	0.5	0.5	0.5	19	9	−22	−26	29	11	−1.7	−1.8
Other Asia	1.1	1.2	1.7	6	19	−12	−26	27	5	−0.7	−2.0
China	2.0	2.8	5.4	−18	−5	−42	−42	22	0	0.0	−1.5
Near East	0.5	0.7	1.0	−10	11	−11	−24	2	71	−1.7	−1.3
Africa	0.7	1.0	1.6	−7	9	2	−8	1	−13	−0.8	−1.3
Developing world means	0.9	1.2	2.0	−2	9	−17	−25	25	13	−1.4	−1.6
Latin America	0.5	0.5	0.4	8	6	−21	−25	22	12	−1.7	−1.7
Other Asia	0.9	0.9	1.5	2	7	−13	−24	33	−7	−0.5	−1.6
China	2.0	2.8	5.4	−18	−5	−42	−42	22	0	0.0	−1.5
Near East	0.2	0.7	1.0	1	6	−10	−26	−5	60	−1.5	−1.7
Africa	0.6	0.9	1.4	0	5	1	−9	−3	−14	−0.8	−0.7
Developing world medians	0.6	0.9	1.4	1.4	6	−13	−25	23	11	−1.2	−1.3

[a]A&P or 'arable and permanently cropped land' is land that is under temporary crops, pasture, gardens and land that is in fallow under 5 years. 'Permanent crops' include land cultivated with crops for long periods of time and which do not need to be replanted after each harvest (e.g. coffee, rubber and fruit trees and vines).

[b]Calculated as follows for 1966–1980: (1980 agricultural production index per 1980 economically active population in agriculture)–(1966 agricultural production index per 1965 economically active population in agriculture)/(1966 agricultural production index per 1965 economically active population in agriculture). The procedure for 1980–1995 is similar.

All land use and production data calculated from FAO (1977a, 1984, 1993c, 1995).

Fertility data calculated from UN (1999).

Migration data are taken from UN (1997).

of Green Revolution technologies and the associated use of inputs. Fertility changes mainly occurred starting in the latter part of the first period – most of the decline in Latin America before 1980 was during 1975–1979 – and accelerated during the second period, as family planning spread through most of the developing world. Meanwhile, out-migration from rural areas was substantial in most regions in both periods, though again slightly higher in the second period.

We now examine the evidence on economic, economic–demographic and demographic changes and tradeoffs in each of the developing-country regions, and compare and contrast them for the two time periods. First, Africa, with a *prima facie* low rural population density (but not low when water supply limitations are taken into account), experienced a modest decline in arable land and in per capita agricultural production during the 1960s–1970s. During the later 1980s–1990s period, rural labour density increased rapidly, despite notable expansion of agricultural land and some out-migration because of continuing high fertility. The economic crisis pervading the region through both time periods, combined with low levels of education, undoubtedly contributed to the lack of increase in agricultural productivity. In the first period, the only response to rising population density was out-migration, but, as pressures on the land increased considerably, in the second period multiple responses are evident, with land extensification, higher rural out-migration and the onset of a fertility decline. Since we expect extensification to precede intensification, in the case of Africa in the latter period, the lack of intensification and the increasing desperation of rural populations may have led to pushing out the agricultural frontier as populations sought land to feed their families.

The Near East has little arable land that is not already used, so increased production has generally been possible only through increased irrigation. However, during the first time period, rural population density remained low and the only response observed was out-migration. But, as the rural population became denser during the second period, the full range of responses occurred, including a large increase in agricultural output per rural worker (presumably as the Green Revolution technology made its way into the region) and an acceleration in the pace of fertility decline, which began to approximate that of other regions. Looking at each period in terms of tradeoffs, in the first period the lack of significant other responses put more pressure on out-migration; in the later period, continuing increases in rural density are associated with multiple responses.

China experienced rapid increases in rural population density in both periods, especially in the second. Agricultural land actually declined significantly in the first period and slightly in the second (the latter confirmed in Heilig, 1999). China rapidly adopted new agricultural technology in the earlier period, but the Food and Agriculture Organization of the UN (FAO) data suggest no further intensification in the latter period (which is inconsistent with recently reported macroeconomic indicators of the agricultural sector). Also, in the first period it is known that China restricted migration to urban areas and imposed a one-child policy, which forced a substantial fertility decline. Whether such policies should be considered completely exogenous or as being themselves induced by population pressures is a moot point, but the changes did occur. In the more recent period, with economic liberalization, changes appear to be primarily demographic, with a continuing rapid decline in fertility and accelerating rural–urban migration. China has evidently experienced the swiftest fertility decline of all regions, in both time periods. In terms of tradeoffs, in the absence of a land response, in the first period, China responded to an increase in rural population density by land intensification and a draconian fertility control policy. In the second period, both fertility decline and out-migration occurred.

In the 'Other Asia' region, rural density increased only slightly in the first period but rapidly in the second, so we would expect much more in the way of responses in the second period. This is indeed the case, with little change in agricultural land or fertility in the first period, and only modest rural–urban migration. The only major change was agricultural intensification, associated with the Green Revolution in India and other countries in the region. In the second period, the changes that occurred were completely the inverse, with little intensification (this having seemingly run its course) but a large increase in cropped land, a decrease in fertility and out-migration from rural areas. In the first time period, the lack of increase in density and the success of intensification deferred pressures to respond in other ways, while in the later period rapidly rising density tended to stimulate multiple responses. Government policies also played a role in encouraging fertility declines in some countries such as India, Indonesia and Thailand. Furthermore, land availability in many countries was associated – as expected – with continued land extensification in the second period.

Finally, in Latin America, rural population density rose slightly in the first period and not at all in the second. Thus, overall, one would not expect many of the changes observed in the suite of economic, economic–demographic and demographic responses to be strongly linked to population pressures in general. In the first time period, substantial extensification occurred, befitting the region's plentiful land endowments. At the same time, agricultural productivity rose and rapid rural out-migration occurred, associated with urbanization, which had begun earlier. Fertility started to drop only in the 1970s in most countries, associated with public- and private-sector family-planning provision and the demand to reduce actual fertility to desired levels, impelled by high levels of urbanization and improved women's education, following cumulative trends over previous decades. In the second period, associated with no increase in density, there was much less agricultural extensification and intensification, but rural out-migration and fertility decline continued. Scant economic opportunities in rural areas, land inequality, considerably higher wages in cities, and the urban bias in development policies contributed to consistently high rural–urban migration: from the 1960s to the 1980s, nearly 2% of rural Latin Americans out-migrated annually (Chen *et al.*, 1998, p. 82). While the changes observed in Table 3.1 in Latin America would appear exogenous relative to changes in population density, substantial differences exist from country to country which may be related to changes in rural population growth and density at the country level (see next section).

Although the data here illustrate broad differences across regions, more empirical work is needed to understand the interrelationships between tradeoffs. In the next section, we examine the agricultural sector in Latin America at the country level, looking at trends in agricultural extensification and intensification and their possible relationships to population change.

Population Density, Land Use and Deforestation in Latin America

Central and South America are different from other developing regions in having much more potential arable land available, more current agricultural land in pasture, higher levels of forests being converted to agricultural land and in being far more urbanized. Amounts of land being deforested were more than double those of other continents during the first half of the 1990s (World Bank, 1998b). But differences are substantial within the region. For the present analysis, it is important to distinguish between Central and South America. First, resource endowments are very different, largely due to the presence of the world's largest tropical forest, the Amazon, which covers parts of eight South American nations. Secondly, fertility has declined far more broadly in South America than in Central America (taken here to refer to Mexico and the Caribbean as well). Taking into account both lower rural fertility and significant net rural–urban migration, the rural population in South America as a whole actually declined slightly from 1984 to 1994. As a result, while mean rural population density in South America was less than half that of Central America in 1966, it has since fallen to about a third.

That there is a strong relationship between population density and the percentage of land area covered by forests is hardly surprising, and is evident at a global level in the differences in the percentage of land area covered by forests in Asia and Europe compared with sub-Saharan Africa and the western hemisphere. A much more sensitive – as well as contemporary and dynamic – test of the relationship is that of first differences – that is, of the relationship between population change and reduction in forest area.

The difference in the two regions of Latin America is significant not only because greater population densities can be expected to be associated with greater cumulative levels of deforestation, but also because countries with small areas remaining in forests can have very high rates of deforestation even when the absolute areas of forests being lost are small (e.g. countries in Central America). Other countries with large forest stocks may experience very low annual rates of deforestation even when the absolute area being cleared is huge (e.g. Brazil).

The usual simple measure of national population density (total population/total land area) ignores the fact that countries have large areas unusable for agriculture (e.g. mountain ranges, deserts, bodies of water and urban areas), and also confuses the issue by combining urban and rural populations. We therefore measure population density by rural population density (rural population per unit of arable land plus land under permanent crops), and use this for analysing population impacts on land use and land-cover change. The numerator is modified through population change (fertility, mortality and net migration), while the denominator is affected by changes in the amount of arable and permanently cropped land. We exclude pastureland from the denominator since it has little direct relationship to population density.

Rural population dynamics, forest-cover change and agricultural extensification

Urbanization and rural fertility decline occurred earlier in South America than in Central America. In fact, during the last three decades, Central America gained approximately 8 million rural residents, while South America lost 3 million. With the exception of pioneering countries, such as Costa Rica and Cuba, where fertility decline began in earnest in the 1960s, it was not until the 1970s that fertility began to fall generally in Latin America. None the less, fertility decline has been delayed in a number of Central American countries (Guatemala, Honduras, Nicaragua and Haiti).

Table 3.2 shows that in Central America, from the 1960s to the mid-1990s, rural population density grew (from 2.2 to 2.4 persons ha^{-1} arable and cropped land), as modest increases in the area of land in crops (29%) were still outpaced by rural population growth. Only in the Dominican Republic and Honduras did growth in agricultural land exceed population growth. In South America, in contrast, greater agricultural expansion, earlier and greater rates of rural–urban migration and earlier fertility decline together led to a slight decrease in overall rural population density, from 1.0 to 0.9 persons per hectare.

Latin America harbours the greatest area of closed tropical forests in the world, with Brazil alone containing a third of the world's tropical forests. The Amazon basin also contains 45% of all the fresh water on the earth, and is the planet's largest carbon sink. Its preservation is thought to be crucial for moderating global warming and regulating global weather systems (e.g. Adger and Brown, 1994; Tinker *et al.*, 1996). Yet Latin Americans have been clearing much more forest than those elsewhere: during the first half of the 1990s, Latin Americans deforested five times more forest per rural person than Africans and 40 times more than Asians (derived from data in FAO, 1997b). Furthermore, reforestation has only minimally compensated for forest losses in Latin America, and far less than in other regions. Thus, in the Asia–Pacific region, reforestation compensated for over 50% of the forest loss from 1981 to 1992, while in Latin America it was around 6% (FAO, 1997b).

It is instructive to examine more closely trends in population and forest cover in the two regions by decade. As is evident from Table 3.3, from 1966 to 1976, Latin America's forest cover decreased only slightly (by 3%), accompanied by a 5% increase in rural population density. But in the ensuing decade or so, from 1976 to 1984, deforestation accelerated sharply in both Central America and South America. High rates of deforestation were accompanied by increases in rural population density of 40% and 8%, respectively. Finally, deforestation in the latest decade (1984 to 1994) was much lower in both regions compared with the previous decade, and was accompanied by increased agricultural intensification, particularly in Central America.

We expect deforestation to be linked to the expansion of cropland and that, at higher rural population densities, a greater proportion of land is likely to be in

Table 3.2. Latin America: rural population density and percentage of land forested.

	Rural population per hectare of agricultural land				Forest land/total land (%)[a]			
Country	1966	1976	1984	1994	1966	1976	1984	1994
Central America								
Costa Rica	1.9	2.4	5.0	3.2	54	50	32	24
Cuba	1.9	1.1	1.1	0.8	14	11	24	22
Dominican Republic	2.8	2.8	2.6	1.9	23	23	13	10
El Salvador	2.9	3.7	4.8	4.3	11	13	6	4
Guatemala	2.1	2.3	3.7	3.2	56	54	42	34
Haiti	4.6	4.5	7.8	5.3	11	7	5	3
Honduras	2.1	2.4	1.6	1.5	63	63	54	43
Mexico	0.8	0.8	1.0	0.9	40	36	25	22
Nicaragua	0.7	0.8	1.3	1.3	49	53	33	26
Panama	1.3	1.6	2.3	1.8	49	55	51	41
C. Am. total	2.1	2.2	3.1	2.4	37	36	28	23
C. Am total[b]	1.1	1.1	1.4	1.3	40	38	27	24
South America								
Argentina	0.2	0.1	0.2	0.2	22	22	19	18[c]
Bolivia	1.3	0.8	1.3	1.2	55	52	53	47
Brazil	1.3	1.1	0.8	0.7	62	60	60	57
Chile	0.5	0.4	0.5	0.5	28	28	22	21[c]
Colombia	1.7	1.8	1.9	1.8	74	74	50	47
Ecuador	1.0	0.8	1.8	1.6	66	65	56	47
Paraguay	1.4	1.6	1.0	1.0	52	51	46	35
Peru	2.1	1.8	1.7	1.6	58	58	53	53[c]
Uruguay	0.3	0.2	0.3	0.2	3	3	5	5[c]
Venezuela	0.5	0.5	0.6	0.4	54	54	36	32
S. Am. total	1.0	0.9	1.0	0.9	47	47	41	37
S. Am. total[b]	0.8	0.7	0.7	0.7	53	52	48	45

[a]Unless otherwise mentioned, all 1994 data on forested land were calculated averaging deforestation rates from 1981 to 1990 from FAO.
[b]Weighted totals.
[c]Estimated from deforestation rates from 1990 to 1995 in FAO (1997a).

crops for human consumption. A correlation between land in crop production and population density is strikingly evident at the regional level. Thus, when rural population densities are computed with the total land area in the denominator, rural Central America was seven times more densely populated than rural South America in 1966 and 11 times more in 1994. When rural population density was measured using only arable and permanently cropped land in the denominator, it was never more than three times as high in Central America during the period. As is evident from Table 3.3, the difference is because Central America had much more arable and permanently cropped land (15% compared with 6% in 1966, and 21% compared with 6% in 1994).

Table 3.3. Extensification: percentage of land in pasture and arable and cropped land.

Country	Pastureland as % of total land		A&P land and pastureland as % of total land		A&P land as % of total land	
	1966	1994	1966	1994	1966	1994
Central America						
Costa Rica	23	46	32	56	10	10
Cuba	24	27	39	58	15	31
Dominican Republic	24	43	43	74	18	31
El Salvador	29	29	59	65	30	35
Guatemala	9	24	23	42	14	18
Haiti	22	18	49	51	27	33
Honduras	18	14	25	32	7	18
Mexico	37	39	50	52	13	13
Nicaragua	28	45	40	56	12	10
Panama	13	20	21	29	7	9
Total (weighted)	32	36	46	51	13	15
Total (unweighted)	23	31	38	51	15	21
South America						
Argentina	53	52	64	62	11	10
Bolivia	26	24	27	27	2	2
Brazil	17	22	20	28	4	6
Chile	14	18	20	24	6	6
Colombia	16	39	21	44	5	5
Ecuador	8	18	20	29	12	11
Paraguay	35	55	38	60	2	6
Peru	21	21	23	24	2	3
Uruguay	78	77	89	85	10	7
Venezuela	17	20	23	25	6	4
Total (weighted)	24	29	29	35	5	6
Total (unweighted)	29	35	35	41	6	6

A&P, arable and permanently cropped.

As illustrated in Fig. 3.2, most agricultural land in Latin America is in pasture. The conversion of forest to pasture cannot be directly linked to rural population growth. Thus, the more densely populated an area, the more likely it is to have land in crops rather than pasture. Indeed, as the rural population grew by 47% from 1966 to 1994 in the already densely populated region of Central America, cropland expansion kept pace with growth in pastureland. Conversely, in less densely populated South America, the rural population increased by only 13% per decade on average and the percentage of cropland remained fixed at only 6% of the continent's land area. Thus, all of South America's 21% net growth in cleared land over the 30 years was due to the expansion of pasture or other land uses. In 1994, South America had five times more pastureland than cropland. Even in Central America the ratio was 3 : 1.

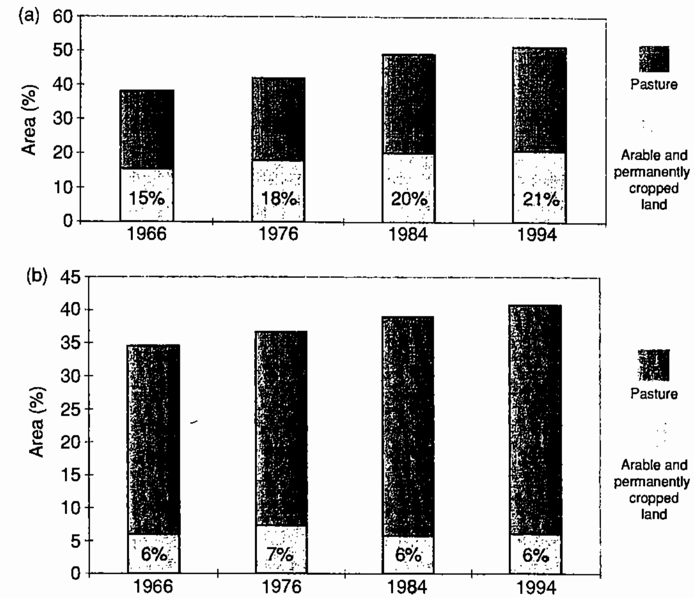

Fig. 3.2. Pasture and arable and permanently cropped land as a percentage of total land (a) in Central America and (b) in South America.

However, it is important to note that much pastureland in Latin America is converted from cropland and not from forests directly (see, for example, Hecht and Cockburn, 1990; Nations, 1992). This is most clear in the case of Brazil, where the total growth in pastureland from 1966 to 1994 equalled the total area of forest eliminated. Below we review land-use changes in more detail, first in Central America and secondly in South America.

Central America

The percentage of forests cleared in Central America in recent decades is astounding. The area in forest extant in 1966 that was cleared by 1994 surpassed the area of forestland remaining in 1994 in all but three countries in the region. Still, the percentage of forests lost was less than the percentage growth in the rural population in every country. For example, Guatemala cleared 38% of its forests, and was left with but 35% of its initial level, while the rural population grew by 97%. Between 1966 and 1994, more than 20% of the total national territory was deforested in Guatemala, Nicaragua and Costa Rica; at over 7% per annum, the deforestation rate in Costa Rica during the 1970s was probably the highest in the world, reducing its stock of forests by over a half in a single decade. Three nations in the region cleared more forests in the 28 years than they had remaining in 1994: El Salvador, the Dominican Republic and Haiti. In these nations, deforestation rates must fall in the future, since there is little left to clear.

South America

As in Central America, forest loss in South America has proceeded at a rapid pace in recent decades. But rural population density is generally much lower than in Central America, and many of the South American countries had no increase in the size of their rural populations over the observation period. As a consequence, changes in rural population density due to net rural population growth cannot explain much of the deforestation in South America. Government policies favouring cattle, especially including subsidies for ranching in Brazil in the 1980s, strong export markets and rising domestic demand from growing and increasingly prosperous urban populations help to explain the large growth of pastureland in South America. In addition, policies to keep the prices of basic grains low to benefit urban consumers at the expense of rural producers have provided incentives for farmers to switch from crops to cattle.

Over the 1966–1994 period, Brazil had the lowest percentage rate of deforestation in Latin America (8%), while its rural population declined by 16%. But, in absolute terms, its area of forest loss, primarily in the Amazon basin, far exceeded that of any country in the world. In industrialized countries such as Argentina and Chile, rural populations also declined but deforestation rose (associated with an increase in timber harvesting and an expansion of export agriculture, rather than with population growth). On the other hand, in a few South American nations – for example, Ecuador and Paraguay – rural population growth may well have contributed to deforestation. In both, forest clearing facilitated an increase in arable and permanently cropped land by nearly a half and a more than doubling of pastureland. By 1994, Ecuador's share of total land in cropland (11%) was the highest in South America, while its share in pastureland remained the lowest, albeit rapidly growing.

Even more than in Central America, however, it is the conversion of cropland and forest to pasture that has been the most dramatic land-cover change. Thus, while Colombia's rural population grew slowly, by only 10% over three decades, pasture grew by 144%, while its crop area remained constant at only 5% of its territory – barely one-ninth the area in pasture in 1994. In Venezuela, the rural population declined 44%, and yet 41% of its forested land in 1966 was still cut by 1994. Evidently, even where rural populations are declining, agricultural frontiers have still expanded.

Although rural–urban migration continues to be significant and to contribute to urban growth,[4] rural–rural migration is of growing importance, with people migrating from rural areas characterized by high poverty and unequal land distributions to other, more remote, rural areas in search of land to continue agricultural livelihoods. Thus, contrary to what some scholars expect, even in countries and areas of overall rural population decline, substantial deforestation can still occur. On the remote frontiers, colonists are migrating along newly established roads, converting forests to cropland and pasture (e.g. Rudel, 1983; Rudel and Richards, 1990; Pichón, 1997a,b; Sader *et al.*, 1997).

A comparison

Despite considerable country-to-country variation, some patterns do emerge. First, where population density is lower, the level of deforestation is lower, but the rate of deforestation per capita is higher (e.g. South American nations compared with Central America; on a global scale, the same comparisons hold for Latin America relative to Asia). Secondly, countries with the highest rural population densities (e.g. Haiti and El Salvador) deforested their land earlier. Deforestation rates remain high because of a shrinking base, but these countries have increasingly lower deforestation rates per rural dweller as forest reserves approach extinction. Thirdly, pastureland accounts for a greater proportion of agricultural land than cropland in Latin America, and its share has risen in recent decades.

To maintain current per capita food consumption levels in coming decades, Latin America will need to greatly increase food imports or increase domestic production through intensification of current agricultural land and/or expansion of the land area in food production. In countries where little forest remains, as in many Central American nations, intensification will be the main option for increasing food production. On the other hand, among South American nations with large endowments of Amazon jungle, extensification is still occurring on a large scale, and could continue. But the sustainability of Amazonian agriculture is dubious as most of the region's biomass is rooted in nutrient-impoverished soils (Buol, 1995).

Agricultural intensification

Starting in the 1950s, international agencies promoted technological advances in agriculture in developing countries in what became known as the Green Revolution. During these years, new seeds were developed for basic grains, and irrigation, pesticide and fertilizer use all grew dramatically. Most of the growth in agricultural production of the past 30 years is attributable to increases in yields per hectare: from 1961 to 1996, global cereal yields increased 107%, while the area harvested increased by only 10% (Bender and Smith, 1997). Only in Latin America has the expansion of the agricultural land area been an important contributor to the expansion of agricultural output, but this share has been declining and is now less than that of increases in yields.

In developing countries, agriculture accounts for 80% of water use (IFPRI, 1996). The growing scarcity of fresh water limits its contribution to increasing agricultural yields in much of the world, though this is not a pervasive problem in Latin America. The percentage of agricultural land irrigated rose from 9% to 14% in Central America and from 11% to 14% in South America from 1966 to 1994. As is evident from Table 3.4, the countries that increased irrigation most were not those with the highest rural population densities or the most rapidly growing populations, but, rather, those with large export operations based on semi-arid and arid lands (Mexico and Peru).

Table 3.4. Indicators of agricultural intensification in Latin America.

Country	Percentage of A&P land irrigated				Fertilizer use (kg ha^{-1} of cropland)			
	1966	1976	1984	1994	1964–1966	1974–1976	1983	1993
Central America								
Costa Rica	5	5	21	24	59	137	171	208
Cuba	29	23	25	27	134	103	164	52
Dominican Republic	13	14	13	17	12	68	39	61
El Salvador	3	5	15	16	71	147	113	106
Guatemala	3	4	6	7	14	36	38	87
Haiti	6	8	8	8	0	2	4	5
Honduras	8	9	4	4	6	12	16	32
Mexico	14	17	20	25	15	42	60	71
Nicaragua	1	5	7	7	17	22	56	21
Panama	3	4	5	5	17	47	40	48
Average[a]	9	9	12	14	34.5	61.6	70.1	69.1
South America								
Argentina	5	5	6	6	1	2	5	11
Bolivia	4	4	6	4	1	1	4	6
Brazil	2	3	4	6	5	31	45	85
Chile	24	22	29	30	26	25	18	58
Colombia	5	6	9	14	28	44	61	94
Ecuador	14	10	21	18	6	14	30	31
Paraguay	4	5	3	3	2	1	5	14
Peru	41	35	33	41	29	38	22	44
Uruguay	2	3	7	11	29	40	31	72
Venezuela	5	6	5	5	10	38	41	65
Average[a]	11	10	12	14	13.7	23.4	26.2	48

[a]Unweighted.
A&P, arable and permanently cropped.

A Sampling of Country Case Studies

The studies summarized below are selected to represent the diversity of experiences across countries and the fundamental effects of contextual factors, such as natural resource endowments and government policy. This is by no means intended to indicate that all cases are equally likely.

Population growth and agricultural extensification

In Ecuador (as well as many other countries with tropical forests), population growth in the Amazon region has led to a widespread process of land clearing and deforestation by agricultural colonists in recent decades. With the discovery of significant petroleum deposits in 1967, oil companies built roads to extract and transport the oil from the northern Amazon starting in the 1970s. This facilitated an influx of migrant colonists, coming largely from the highlands (Pichón, 1997a; Pichón and Bilsborrow, 1999). Population grew at annual rates of 8% in 1974–1982 and 6% in 1982–1990 – in both cases more than double the national average – while deforestation was widespread in the region and led to Ecuador's overall annual deforestation rate of 1.8%, the highest of any Amazon basin country. By the time of a detailed household survey of migrant colonists in 1990, 44% of the colonists' plots (most 40–50 ha) had been deforested. Ongoing work in the region by Bilsborrow and others indicates continuing rapid population growth and agricultural extensification, due as much to high fertility in the region as to new in-migration.

Population decline and agricultural extensification

In apparent contradiction to theory, in the Brazilian Amazon during recent decades, deforestation has accompanied a declining rural population; the rural population decreased by 16% from 1966 to 1994 and, since the early 1980s, even the rural population in the Amazon has not grown. Poor tropical soils, underdeveloped transportation infrastructure, titling delays, tenure insecurity and lack of credit severely constrained the agricultural development prospects of many migrant farmers within a few years of their arrival. Many migrants abandoned their farms to work in mining or timber harvesting or to move to cities. Large-scale ranchers engaged in speculation, buying up land and sometimes forcefully removing farmers (Hecht and Cockburn, 1990; Stewart, 1994). Much of the abandoned land was converted to pastureland, which is a far more extensive use of land than growing crops, contributing to ongoing deforestation, despite a decreasing rural population.

While demographic factors appear absent as proximate causes of this process, both high (earlier) fertility and migration are among the underlying factors. Many of the migrant settlers initially came from north-eastern Brazil, where high fertility, extreme land inequality and recurrent droughts led to population pressures on the land and poverty, which impelled the population to migrate in search of solutions, mostly to cities but many to the Amazon frontier as well. It is striking that, in both Brazil and Ecuador, a decline in overall rural population density is associated with rapid deforestation at the national level, due, in large part, to rural–rural migration from densely populated areas to the Amazon.

Population growth and agricultural intensification

A direct link between rural population change and land-use change can be ascertained better when confounding economic and political variables are absent. Such is the case in traditional (non-monetized) agrarian societies, which are rare today. However, some scattered evidence providing a quantitative test of Boserup's intensification hypothesis has been brought together based on data from studies of 29 tropical subsistence agricultural societies around the world

(Turner *et al.*, 1977). Turner and colleagues observed a significant positive cross-sectional relationship between population density and agricultural intensity, with the latter measured as the proportion of time the agricultural land was in use.[5] The best fit was from an exponential model, suggesting that agricultural intensity is much higher as population density rises – evidence in support of diminishing returns.

A later study by Turner and Ali (1996) examined the link between growing population density in six villages (265 households) in Bangladesh from 1950 to 1986. They noted that the lack of available unused land dictated intensification as the only agricultural response (91% of the land was cultivated at least once per year). Yet population density differed greatly across the six villages, with three much more densely populated than the others (means of about 1200 persons per square kilometre in 1985/86 versus about 500 in 1950); land productivity was over twice as high in the former villages, as was the cropping frequency. Higher intensification was also linked to fewer environmental constraints, being closer to markets (Dacca) and having received more government assistance.

Finally, in a study on three districts of Tanzania, Meertens *et al.* (1996) observed changes over a century based on historical records and recent field studies. They concluded that increasing population densities have led to intensification, but that the process has been shaped by agroecological conditions (such as differences in rainfall and type of land). They also noted that the land frontier was exhausted first, followed by out-migration, before intensification occurred.

Population growth and out-migration

Among the several recent studies on Africa, that of Netting *et al.* (1989) stands out. They looked at how the Koyfar of the Jos Plateau in Nigeria adapted to population growth between the 1950s and the 1980s. For decades before, much of the population migrated seasonally to the nearby Benue valley (lowlands) to grow yams to supplement their subsistence production in the plateau homeland. The rapidly growing internal market for yams led to this migration eventually becoming permanent for over half the families. Another demographic response then occurred, with the need for labour leading to increases in both polygamy and multiple household units (fertility was already high). The serendipitous linkages are directly related to the atypical advantages of having a large area of unused, unowned, fertile land nearby, as well as a growing market for yams. Finally, it was noted that certain cultural factors also played important roles in the positive adaptation – household autonomy, work ethic and lack of local autocratic rulers and institutions.

Population growth and multiphasic responses

Research which has attracted considerable attention recently is that of Tiffen and colleagues on the Machakos district, near Nairobi, Kenya (Tiffen and

Mortimore, 1994; Tiffen, 1995). Even as population grew fourfold over the period 1930–1990, the value of agricultural output per capita tripled, mainly from huge increases in the production of cash crops in the 1960s–1970s and in horticulture in the 1980s, while livestock production declined. This reflects a more intensive use of land, as expected by Boserup (1965). Meanwhile, environmental conditions actually improved, with reforestation and the creation of broad labour-intensive bench terraces, both of which saved water and reduced erosion. Still, other changes also occurred, together comprising a multiphasic response, with the first in the 1930s being extensification of agriculture to inferior land and substantial out-migration of males for wage labour, both prior to intensification. Indeed, remittances and savings of the out-migrants later financed an increase in education (human capital) and the creation of non-farm businesses, which probably contributed to the later intensification. More recently, increases in local employment opportunities (including non-farm) have led to a decline in male out-migration. Finally, a demographic transition now appears to have begun since the 1980s, which may reflect increasing difficulties in achieving further extensification (there being no unclaimed land by 1980 (Tiffen, 1995)) or intensification (the value of output per hectare failed to rise as much as population during the 1980s (Tiffen, 1995)). Nevertheless, it should be noted that in Kenya, generally, fertility is now declining, as policies initiated in the 1970s begin to find 'fertile ground'.

Summary, Gaps in Knowledge and Research Needs

The data presented here on linkages between population dynamics and changes in land use in Latin America and other developing regions of the world suggest that neither neo-Malthusian nor Boserupian models offer satisfactory explanations of population–environment linkages. Complex processes are difficult to disentangle on a country scale. Subnational data for provinces or even smaller political units are better suited for testing the interrelationships because they permit taking into account additional factors, including contextual factors that differ from one area to another.

Evidence of linkages between population dynamics and the various economic, economic–demographic and demographic responses appears stronger in other regions than in Latin America for the 1960s to the mid-1990s. This is because, unlike in the other regions, rural population density in Latin America rose only slightly during the first half of that period and actually fell during the latter half. Thus, at a continent-wide level, it is not plausible to expect a relationship between changes in rural density and induced responses, since there was nothing inducing the response. However, this does not mean that such relationships did not obtain for some countries in the region, as discussed above.

Unfortunately, a major shortcoming of cross-continent and cross-country (Latin America) studies, such as those summarized here, is the egregious lack of reliable and comparable data, with the result that many of the data used are based only on 'guestimates' by officials in the countries or at the FAO. For example, few countries in Latin America or Africa carried out national agricultural censuses in the 1980s or 1990s. Although studies of the same relationships (using appropriately different measures) based upon farm-level data could be even more useful than those based on census data for testing population–extensification/intensification linkages, few data sets are available.

With these caveats in mind, let us briefly review some patterns that emerge on population and land-use/land-cover patterns during recent decades (1966–1994) in Latin America, focusing on the differences between Central and South America. Rural population densities in South America were already starting to decline by the early 1980s or before. This was due both to the opening up of new lands for agriculture in frontier areas (mainly forests) and also to declines in fertility and out-migration from rural areas by people searching for better opportunities in urban areas and frontier regions. In Central America, in contrast, the rural population continued to grow throughout the 1966–1994 period in virtually all countries. Rural Central America was seven times more densely populated than rural South America in 1966, but 11 times more in 1994. As a result, the connection between population dynamics and land-use change should be greater there.

However, even in countries such as Brazil, where rural population density is declining, demographic factors are important underlying factors in the expansion of the agricultural frontier and deforestation. One key factor is rural–rural migration, rather than high or rising rural population density due to high population growth and high fertility. Thus, it is crucial to ascertain the origins of rural–rural migrants – and conditions in the places of origin – to determine the ultimate causes of that migration and hence of the forest degradation that occurs in other parts of the country.

The fact that extensification has continued unabated where land is available is sobering, given diminishing forest reserves worldwide and the ecological imperative of tropical forest conservation. Economic and demographic changes have contributed to the widening gap between those regions moving towards rapid rural and overall development (China, South-east Asia and some countries in Latin America) and others which are stagnant (Africa and much of the rest of Asia and Latin America). While demographic responses, especially further fertility decline towards replacement fertility, may help in confronting these problems, and while some further extensification will prove necessary, mechanisms need to be found to achieve much more successful intensification of agriculture, especially in the poorer regions of the Third World.

Unfortunately, there are growing signs of limitations to intensification. The FAO estimates that two-thirds of the global increase in agricultural production from 1990 to 2010 will need to come from increasing yields, with only 21% from expanding the land area and 13% from increasing crop intensity in the sense of shorter fallow periods (WRI, 1996). But the cost of expanding production is rising. Of the remaining potentially usable land, half is already in protected forests, while three-quarters has serious soil or terrain (topography, drainage, etc.) constraints; meanwhile 10% of current agricultural land is already moderately or severely degraded (WRI, 1996). By the early 1990s, three-quarters of the world's wheat and rice acreage and half the land in maize were already in high-yielding varieties (HYV). And irrigated land, accounting for one-third of the world's agricultural production (with 60% of the irrigated land in Asia, and only 5% in Africa and 4% in Latin America), is increasing at a slower rate, growing 2% per annum in the 1970s and 1980s but at less than 1% in the 1990s (WRI, 1996). The main inputs expected to contribute to further intensification are chemical fertilizers, the usage of which is expected to double during the period 1990–2010. Chemical fertilizer usage levels in Africa are currently only one-seventh of those in Asia. Still, increases in fertilizer use have led to smaller increments in production in recent decades (Brown, 1997).

With continued population growth, diminishing available land and future intensification constraints, policy-makers at all levels will be challenged to improve the agriculture–population nexus in developing countries. Successful policies may include: (i) helping rural farmers intensify production through more technical assistance and credit targeted to raising crops rather than cattle; (ii) improving access to reproductive health and family-planning services in rural areas; and (iii) better conserving what is left of the precious vestiges of tropical forest through higher royalties for logging concessions, more rational road-building policies and involving local populations in protecting conservation areas.

Notes

1 Among the nations of the temperate regions, only Finland and Japan (at approximately 0.2% annually) reported positive deforestation rates in the 1990s (World Bank, 1998b). In contrast, all tropical nations are experiencing deforestation at a rate of 0.5% or greater annually.

2 A more extreme version of Boserup's hypothesis, which is discredited by empirical evidence, is that population growth is automatically a boon to the developing world by inducing technological innovation, enabling output to rise faster than population (Simon, 1977, 1981).

3 The use of the same five regions continues to present difficulties for the Near East, which we intended to comprise all countries from Morocco across northern Africa and western Asia to Afghanistan. However, because of the almost total dependence on oil of many countries and/or the lack of adequate data (e.g. Syria, Algeria, Morocco, Tunisia), the final sample comprised only four countries – Egypt, Iran, Iraq and Jordan. In these countries, a couple of values seemed implausible and were omitted, namely, the increase in agricultural productivity in Iraq of 158% in 1980–1995 implied by FAO data.

4 Chen *et al.* (1998) find that rural–urban migration accounts for about two-fifths of urban population growth in the region, with the rest due to natural population growth (the difference between the fertility and mortality of the urban population).

5 The standard definition was used. Land in use one year followed by 4 years in fallow would yield an intensification measure of 20 (20% of the time), while land used for double-cropping in a year leads to a measure of 200.