Agricultural Change and Limits to Deforestation in Central America

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INTRODUCTION

In this chapter we discuss trends in agricultural land use in Central America between 1961 and 2001, and how they point in the coming decades to changes in regional production patterns, changes in agricultural systems, and regional forest cover. First, we introduce some concepts of sustainable agricultural development and its significance for the transformation of agricultural land use, and consequently the sustained wellbeing of coupled human and natural systems. We then discuss limits to deforestation in Central America as a result of trade-offs between agricultural production and natural resource conservation, in the light of efforts to achieve sustainable rural development, and review some recent trends among the peninsular Central American nations (Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama). In particular, we explore trends in agricultural intensification, with capital and land intensive practices in food production, as an increasing response to land scarcity, and thus constituting an important factor in efforts to minimize agricultural extensification, the increase in food production through the expansion of farmland usually at the expense of forest conversion. Finally, we examine regional and national food production and forest cover trends over the last several decades in Central America. Forest cover change is based on FAO estimates of forest and woodlands while changes in agricultural production are examined jointly with its key inputs: land, labour, and capital for the period 1961 to 2001.

How to achieve a balance between socioeconomic development and the quality and quantity of environmental resources for present and future generations? This is the sustainable development conundrum. Whether current notions of sustainable development offer viable alternatives to antagonistic positions of doctrinaire development advocates and strict environmental conservationists cannot be foretold. But the intentions are clear as presented by Brundtland Report's (1987) definition as: 'development which meets the needs of the present without compromising the ability of future generations to

F. Brouwer and B.A. McCarl (eds.), Agriculture and Climate Beyond 2015, 91-107.

meet their own needs.' Following this definition, sustainable agricultural development is the maintenance of future production and consumption needs, which implies a sustainable interaction between humans and the environment. An adequate food production to meet food demand over time implies potential trade-offs relative to the sustenance of rural livelihoods and forest conservation. Balancing continued improvements in agricultural output on decreasingly available arable lands while limiting agricultural expansion to forest ecosystems is critical in a world of over 6 billion and growing. In recent decades agricultural intensification has meant that yield increases have handily outpaced increases in agricultural land expansion. Indeed in much of the developed world agricultural land has declined, a forest transition that has yet to take purchase throughout the developing world.

A forest transition occurs when net deforestation gives way to net reforestation. The orthodox transition theory posits that forests tend to shrink initially and expand again later at higher levels of economic development (Mather et al., 1999). Such a transition results in the concentration of agricultural production in smaller areas of better land and the agricultural abandonment of larger areas of poor land. As this pattern develops, relatively larger areas of poor quality land become available for reforestation through natural regeneration or planting (Mather, Needle 1999). Forest-transition theory thus suggests that economic development eventually leads to forest recovery, but much is unknown about the existence, the characteristics, and the mechanisms of forest transitions that might be occurring under current socioeconomic conditions. Further, incipient stages of the transition are characterized by geographical heterogeneity. For example, Klooster's study in highland Mexico finds forest degradation to be caused by woodcutting despite the presence of agricultural abandonment and forest regeneration (Klooster, 2003). Regional variation in forest transitions has increasingly been framed within the uneven evolution of institutions that coordinate rural peoples' land use. For example, in a highland Mexican community, Klooster and Masera (2000) benefits from forestry increased dramatically after community control management improved. Thus it is argued that community forest management offers concrete local benefits while at the same time helps to conserve forests and to sequester carbon. Indeed, the Clean Development Mechanism (CDM) of the Kyoto Protocol was established to leverage additional resources to promote such an approach.

The outcome of food production versus forest conservation trade-offs has important human and environment implications. With most of the best farmland already in production, much of the world's forest elimination occurs on oxidized, nutrient-leached soils, unsuitable for agricultural development (Moran, 1983). Farmers in such regions are among the poorest of all rural inhabitants (Leonard et al., 1989), and suffer a litany of problems, including poor access to roads, potable water, schools, and health care (Murphy et al., 1997).

Short-term financial gains from tropical forest conversion mortgage scientific advances in medicine, and food production as biodiversity is compromised (Smith and Schultes, 1990; Wilson, 1992). This is particularly the case in tropical environments where approximately 90% of species extinctions occur (Myers, 1993). Deforestation also causes soil erosion and watershed sedimentation

(Southgate and Whitaker, 1992), nutrient leaching (Lal, 1996), and perturbations in nutrient cycling (Fearnside and Barbosa, 1998).

Land conversion from forests to agriculture and pasture has been associated with climate changes at the global scale (Fearnside, 1996). While developed countries have contributed to much of the planet's recent warming trend by burning fossil fuels and via industrial compounds, Adger and Brown (1994) estimate that tropical deforestation is responsible for between 25% and 30% of the purported climate warming in the world; and forests are responsible for about 90% of the carbon stored in global vegetation (Dale, 1997). Furthermore, climate change is believed to affect world food supply and productivity (Brown, 1994). This situation has led to reforestation efforts in developing countries as a way to reduce carbon emissions.[1] Reforestation can help to break down excess atmospheric carbon dioxide and contribute to the recycling of moisture and the reduction in reflectivity of the earth's surface (Myers, 1989).

Forest conversion is also linked to climate changes at the local scale (Shukla et al., 1990; O'Brien, 1995; Tinker et al., 1996). Deforestation can alter patterns of reflectance of the earth's surface and consequently induce local warming or cooling (Dale, 1997). Furthermore, aggregate local-level forest clearing contributes to global warming through the emission of carbon dioxide and other greenhouse gases to the atmosphere (Klooster and Masera, 2000). In Latin America, Laurance and Williamson (2001) suggest that deforestation in the Amazon has reduced regional rainfall and increased the vulnerability of forests to fire.

Nowhere are interactions among competing demands between humans and forest systems more dynamic than in Central America (Figure 6.1). Central America has cleared a greater percentage of its forests, most all of it for food production, than any major world region in recent decades. Agricultural land expansion and food production outpaced rapid population growth during this period. Most forest clearing for agricultural expansion, however, has occurred on lands marginal for production while often rich in natural biodiversity and ecosystem functioning. Conversely, virtually all growth in food production has occurred on capital-intensive plantations developed mainly for export dollars. To the extent growth in the latter exceeds that of the former, food production increases are achieved with relatively minimal destruction of forest resources. Nonetheless growth in large-scale food production has accompanied other problematic impacts on rural human and natural landscapes. Capital intensive production has displaced thousands of rural farmers - most of them out-migrating to urban areas, but also to marginal lands rich in biodiversity and forest resources - and also involves other ecological alterations, such as chemical runoff into riverine, lake, and ocean ecosystems, and soil degradation. Sustainable agricultural practices in this dynamic region will be necessary to balance the demand for food and requirements of environmental conservation and reducing gas emissions to the atmosphere. We now briefly review the state of some of those efforts.

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[1] However, following the Marrakesh round of the Kyoto negotiations it was decided that carbon credits could not be issued for avoided deforestation.

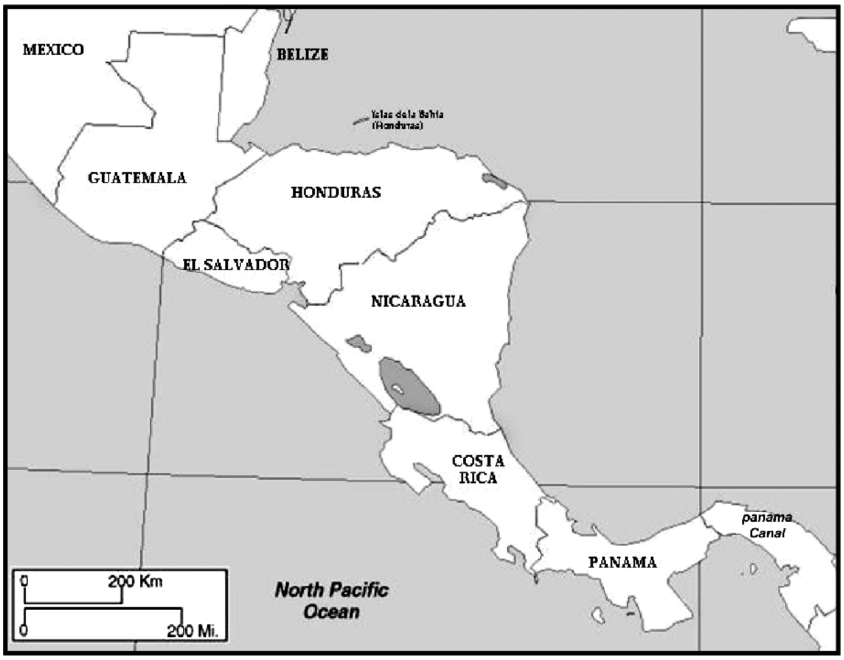

Figure 6.1 Map of Central America

RURAL SUSTAINABLE DEVELOPMENT EFFORTS

The promotion of sustainability as an instrument to reconcile economic development with the conservation of natural resources was first advanced in earnest at the Earth Summit in Rio de Janeiro in 1992. The main document emerging from the historic meeting, Agenda 21, underscores the intimate relationship between poverty and environmental degradation in developing countries, along with the unsustainable pattern of consumption in developed countries (United Nations 1992). A major conclusion of the *Agenda* authors was the need to maintain and improve the capacity of the most productive agricultural land to support an expanding population, while at the same time to implement measures towards conservation and rehabilitation of natural resources (land, water, forests) on less productive lands. Many scholars argue that a primary means to achieving this outcome is through the promotion of sustainable intensification techniques (Tisdell, 1988; Tisdell, 1999; Lee and Barrett, 2000). However, as explained in the following section, agricultural intensification, increasing output per unit of land, is far from a panacea with diminishing returns to inputs and potentially deleterious impacts for humans and the environment.

To date policy prescriptions have insufficiently reconciled the tension between the imperative for economic development and the desire for environmental conservation in rural regions of developing countries. Many of the poorest Central Americans are situated in rural populations concentrated on marginal, less productive lands. Given the lack of access to capital, land security, credit and alternative income sources, poor farmers are more likely to adopt short-term land use strategies to maximize income. Often this has meant overexploitation of available resources, including land degradation and the depletion of soil fertility, and subsequent agricultural expansion to other marginal lands, especially lowland tropical lands, with further land degradation ensuing in a vicious cycle as farmers attempt to compensate for declining yields (Barbier, 2000).

A host of authors have called recently for policies integrating the three pillars of human, environmental, and food sustainability in agricultural systems. Advocates of this 'eco-agriculture' approach aim to address these three issues concomitantly and, consequently, to create systems that produce food and safeguard wild lands and essential ecosystem services. To quote the authors of a recent book on the topic: 'enhancing rural livelihoods through more productive and profitable farming systems is a core strategy for both agricultural development and conservation of biodiversity' (Mc Neely and Scherr, 2002). We now examine some trends in trade-offs between deforestation and agricultural development in Central America.

SUSTAINABLE AGRICULTURE IN CENTRAL AMERICA

Agricultural trade-offs to mitigate deforestation

Throughout the developing world, the scarcity of remaining land resources means that capital and land intensive agriculture represents an increasing share of the overall means to food production. Growth in food production slowed worldwide starting in the 1960s (World Bank, 1995). Half of potentially arable unused land remains locked (*de jure* if not *de facto*) in protected lands, and another three-fourths has soil or topographic limitations. Further, over 10% of land currently in production is substantially degraded (World Bank, 1995). This is particularly the case in Central America where forest cover decreased at an average rate of 1.2% per year from 1961 to 2001 (Figure 6.2). With just over half the original 1961 forest cover remaining, future increases in agricultural production in Central America will likely take the form of more intensive agriculture rather than agricultural expansion as in, for example, the Amazonian nations.

Even if food production is sustainable over time, maintaining production to keep pace with growing demand has implications for the environment and rural livelihoods. Land allocated to pasture and permanent crops (perennials) in Central America has increased about 40% (13 percentage points) from 1961 to 2001 (Figure 6.3) with a simultaneous increase in production of 170% (Figure 6.4).[2] Most of the extensification noted in Figure 6.3 is due to the expansion of pasture rather than arable and cropped land; therefore, the increase in agricultural production can most likely be attributed to intensification over time. However, while the purpose of most forest clearing is for agricultural expansion, the flip

[2] Net production is computed by FAO as (Production – Feed – Seed).

side of the coin is habitat destruction. In Central America, forest conversion increasingly occurs on dwindling remnants of biodiversity-rich tropical forests, often in and adjacent to protected areas (Brandon and Wells, 1992; Rudel and Roper, 1996). As much as 90% of species extinctions (over 20,000 annually, according to Myers, 1993) have occurred in tropical forests, though these regions make up a fraction of the world's land cover. These processes impoverish Central America's considerable gene pool, a potential gold mine for scientific advancements and food production (Smith and Schultes, 1990; Myers, 1996).

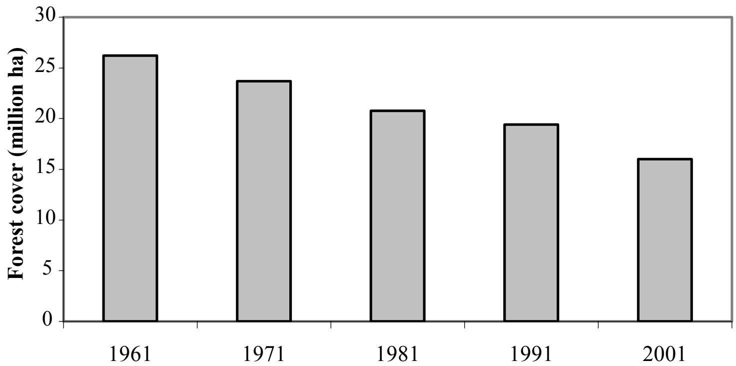

Figure 6.2 Total forest cover (million ha) in Central America over time

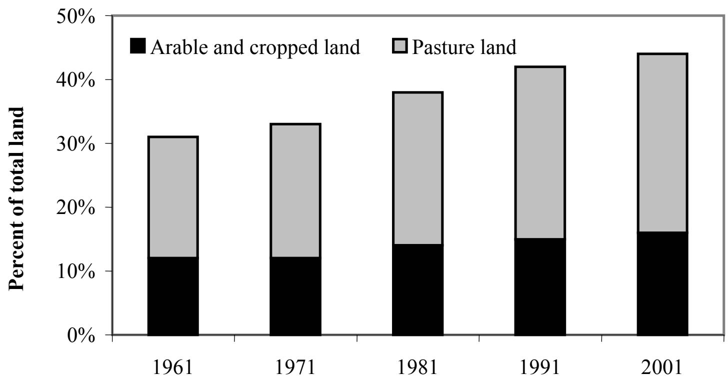

Figure 6.3 Agricultural extensification by year in Central America

Agricultural intensification also poses severe problems for environmental sustainability and the maintenance of agricultural inputs. Examples include waterlogged soils and alterations in water table levels in areas of intensive use of irrigation; salinization; water and soil contamination with excessive and inappropriate use of chemical inputs; and loss of genetic diversity in areas of monoculture, with higher vulnerability to pests and the weather (Ruttan, 1994). Further, increasing agricultural intensification in developing countries has threatened the quality of surface and groundwater due to the runoff of plant nutrients and use of pesticides, with increases in the former posing an increasing threat to the health of rural workers (Crissman et al., 2000).

Land degradation and health problems are not the only impacts on rural residents originating from agricultural and environmental change. Figure 6.5 shows the gradual decreasing trend of people in Central America living in rural areas, with the largest drop occurring between 1991 and 2001. Despite rapid urbanization in recent decades, nearly half of the population still resides in rural areas, and virtually all of them work in agriculture. This is particularly important since the majority of Central America's poorest inhabit rural environments where natural population growth remains considerably higher than in urban locales. Despite notable progress in some rural areas, particularly in Costa Rica, the majority of rural Central Americans eke a living from pauperesque plots or are landless. In both cases, the sale of one's own labour is often the main strategy for earning capital (Leonard et al., 1989). Rural people are disadvantaged in their access to roads, water, public works, schools, health care, and other government investments (Murphy et al., 1997; Pichón, 1997). Yet when development reaches the countryside, food production systems tend to change from labour to capital intensive, pushing small farm families off the land, often to cities where their agricultural skills offer meagre comparative advantage in urban labour pools. Inexorably, this process marches on - perhaps necessarily so if food production is to continue to keep pace with demand. Nevertheless, a host of socio-economic and political-ecological forces enable and constrain local land use decisions. We will now discuss some of these determinants.

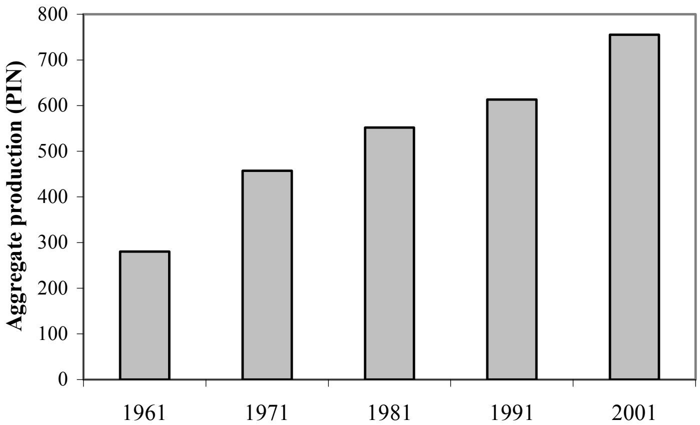

Figure 6.4 Agricultural production by year in Central America[3]

[3] The FAO indices of agricultural production measure 'the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 1999-2001. They are based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a

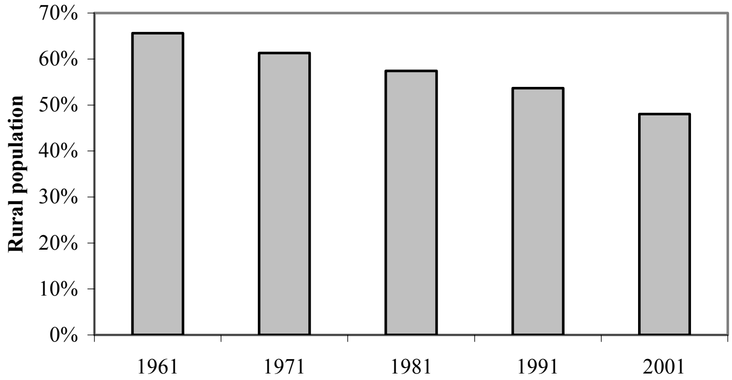

Figure 6.5 Rural population (%) in Central America

Determinants of agricultural production and forest cover change

Given the heterogeneity of coupled human-agricultural systems across the world, it is critical to understand the meaning of rural agricultural and livelihood sustainability in terms of local and regional contexts (Bowler et al., 2001). The most traditional agricultural system in Central America is the maize-beans tandem, which together with coffee, intensive small-scale irrigated vegetable production and seasonal migration of wage labour to lowland and coffee estates, are the main sources of farm income (Food and Agriculture Organization of the United Nations (FAO), 2001). As in other developing regions, sustainable agricultural development in Central America is challenged by a myriad of factors including rural poverty, population dynamics, and institutional factors, such as absence of credit markets, land insecurity and inappropriate land management (Bilsborrow and Carr, 2000).

While some studies have found a 'Boserupian' pattern in Central America, i.e., a positive relationship between population density and farm yields (Carr, 2002), the question remains as to whether technological advancements will continue to overcome challenges to agricultural sustainability such as soil overuse, inadequate land management, and natural resource degradation (FAO, 2001). The region has experienced rapidly falling (but still high in rural areas) fertility and rural-urban migration in recent decades. An understudied demographic challenge to agricultural sustainability in Central America is population momentum. In addition to the high population density of the region, the young age-composition promises that future demand for land and natural resources will challenge current agricultural systems. The population density in

similar manner. The resulting aggregate represents, therefore, disposable production for any use except as seed and feed' (www.fao.org/waicent/faostat/agricult/indices-e.htm).

the region in 2002 was 57 people per km^2 (compared to the Latin America and Caribbean average, 26 per km^2), while 34% of the population was below 15 years old (United Nations Population Division (UNPD), 2003). Thus, even with drastic fertility declines in the next years, the current high proportion of population in younger age groups will assure high population growth in the coming decades. Population pressure - along with land concentration as measured by a high Gini coefficient of land distribution - has been a primordial reason for the usually small landholdings in Central America - less than 2 ha on average (FAO, 2001), a land size insufficient with current economic development patterns to alleviate poverty and assure food security. Consequently, small farmers are unlikely to adopt environmentally benign agricultural practices if they do not translate into income gains or improved food security (Mc Neely and Scherr, 2002).

Decreasing farm income and deterioration of wages, due to a combination of trade liberalization and the protection of national production, has also induced the overexploitation of existing resources and environmental degradation (Dragun, 1999; FAO, 2001). Agricultural sustainability in a population-dense world is predicated on scientific and technological developments, which require investment in, for example, credit markets and governmental technical assistance. However, for small farmers, imperfect markets, the paucity of credits for agricultural investments, and the middle or long-term returns required by more sustainable agricultural practices are usually incompatible with the short term demands of food security and other household needs. Similarly, the adoption of conservation measures such as agroforestry systems, usually involves large-scale production, with large amounts of land, labour and capital resources (Current et al., 1995).

Small farmers are the primary agents expanding the agricultural frontier in tropical lowland areas, a recurrent phenomenon throughout the Central America nations (Jones, 1990). Expansion of agriculture threatens common natural resources in protected areas, as is the case, for example, in Guatemala's Petén (Carr, 2001) and throughout the national park system of Costa Rica (Sánchez-Azofeifa et al., 2003). Barbier (1997) suggests that deforestation in tropical lands was responsible for 22% of soil erosion in Central America over the period 1945-1990. Lutz et al. (1998) suggest that 56% of total land in Central America has experienced moderate degradation (with substantial reduction in productivity), and 41% has experienced strong degradation (agricultural use becoming impossible). Such patterns have not arisen only as responses to the physical environmental, but also to changes in policies promoting the occupation of fragile lands and the adoption of extensive land practices such as cattle (Loker, 1993; Turner II and Benjamin, 1994). However, agricultural extensification and land degradation are not a *fait accompli*. Some encouraging patterns have been observed in Central America in terms of safeguarding habitat integrity, species diversity, agricultural supply and rural livelihoods (Mc Neely and Scherr, 2002).

While noting the importance of local variation, the focus here is to delineate regional-level trade-offs between forest conversion for agricultural extensification and agricultural intensification through human, land, and capital inputs. We will now explore some regional variation in agricultural change in Central America. The following section of the chapter addresses the methodology used in this examination, followed by a presentation of results in agricultural production trends and changes in the means to sustaining agricultural production. We will then interpret the findings to speculate on the sustainability of these recent patterns for continued food production as forest resources dwindle.

REGIONAL VARIATION OF AGRICULTURAL CHANGE

Methods

Data come from the Food and Agriculture Organization's Agricultural Yearbooks, as well as FAO online statistical resources (www.fao.org). We examine key indices of agricultural production between 1961 and 2001 for six Central American countries, and seek to interpret trends in food production sustainability. Indices examined include total forest cover in hectares (ha), percentage of land in agriculture, rural population, and fertilizer use. In exploring the means to production we examine changes in rural population, agricultural extensification (in the form of arable, permanently cropped land, and pasture), and intensification through the use of fertilizers. Lastly, based on forest cover change patterns, we speculate on the extent to which increases may occur through continued agricultural extensification. These are but a subset of a broader series of variables that ultimately must be researched to achieve a more complete analysis of sustainability trade-offs for agricultural, human, and environmental systems. Although a more in-depth data analysis is beyond the scope of this chapter, we consider potential variables and forms of analysis in the conclusion.

Agricultural extensification, intensification, and production in Central America: 1961-2001

As shown in Figure 6.2, total forest cover in Central America declined approximately 40% between 1961 and 2001. Several countries lost nearly half their forest cover, including Nicaragua, Guatemala, and El Salvador during this period. Table 6.1 shows the loss of forest cover by country in total ha. Nicaragua and Guatemala, with the majority of their land cover in forest in the 1960s, experienced the highest level of total forest cover loss of 3.4 million ha and 2.7 million ha respectively. Obviously such trends are unsustainable; when projecting recent trends merely several decades into the future the Central American nations would become devoid of all forest cover.

Pasture land and arable and permanently cropped land expanded steadily in Central America between 1961 and 2001, with total land in agriculture for the region increasing from 31% in 1961 to 44% in 2001 (Figure 6.3 and Table 6.2). Honduras was the only country to experience an overall decrease in pastureland and arable and permanently cropped land during this period. We are dubious of the reliability of these data based on case studies from Honduras describing substantial agricultural expansion (Stonich, 1996; Godoy et al., 1998; Humphries, 1998; Jansen, 1998), though there appears to be recent reforestation in some regions (Southworth et al., 2002). Costa Rica and Guatemala underwent the most agricultural extensification between 1961 and 2001, while El Salvador, Nicaragua, and Panama all experienced roughly 37% agricultural expansion. Increases in agricultural land in Costa Rica, Guatemala, and Panama were primarily due to expansion of pasture, while increases in El Salvador, which had the highest proportion of land devoted to agricultural use consistently over the entire period, were primarily attributed to expansion in arable and cropped land. Nicaragua experienced an initial increase in pasture land from 1961-1981 followed by a subsequent increase in arable and cropped land with pasture plateauing from 1981-2001.

Table 6.1 Forest cover by year and country (1,000 ha)

Country	1961	1971	1981	1991	2001
Costa Rica	3,240	2,490	1,730	1,570	1,790
El Salvador	208	178	134	105	107
Guatemala	5,370	5,070	4,470	5,212	2,717
Honduras	6,000	6,000	6,000	6,000	5,335
Nicaragua	6,650	5,510	4,370	3,270	3,232
Panama	4,740	4,440	4,070	3,260	2,836
Total	26,208	23,688	20,774	19,417	16,017

Table 6.3 shows the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 1989-91. Agricultural production nearly tripled from 1961 to 2001, a trend inversely related to forest cover, as one might expect, in the absence of agricultural outputs responding exclusively to intensification. However, much of this growth occurred during the 1960s and 1970s. Between the years of 1961 and 1981, total production nearly doubled; however, the rate of total production slowed to an increase of 36% between 1981 and 2001. In contrast, forest cover decreased 21% between 1961 and 1981 and 23% between 1981 and 2001.

Table 6.2 Share of land in agriculture by year and country (%)

Country	1961	1971	1981	1991	2001
Costa Rica	27	37	51	56	56
El Salvador	60	61	64	71	82
Guatemala	24	26	29	40	42
Honduras	27	27	29	30	26
Nicaragua	42	46	51	52	58
Panama	22	23	23	29	30
Average	31	33	38	42	44

Table 6.3 FAO aggregate agricultural production by year and country[a]

Country	1961	1971	1981	1991	2001
Costa Rica	29	54	70	106	142
El Salvador	63	85	101	105	104
Guatemala	38	58	85	101	132
Honduras	43	72	93	102	127
Nicaragua	62	115	116	101	144
Panama	45	73	87	98	106
Total	280	457	552	613	755
Average	47	76	92	102	126

[a] Net PIN base 1989-1991. The Net Production Index Number (PIN) is computed by dividing the aggregate for a given year by the average aggregate for the base period, following a Laspeyres formula.

While the rate of forest decline remained similar between 1961 and 2001, the pace of increase in agricultural production drastically decreased after 1981. Costa Rica led the region with a nearly five-fold agricultural production increase, accompanied by the highest increase in land converted to agriculture over the time period. Output in the remaining nations more than doubled, with the exception of El Salvador, whose total agricultural production increased 65%.

Due to a substantial increase in rural labour productivity per capita, agricultural production increased during the time period while rural labour pools shrank. Rural population as a percentage of total population in Central America decreased by 27% between 1961 and 2001. Honduras, Costa Rica, and El Salvador experienced the largest and most rapid decreases in percent rural population, each with its 2001 percent rural representing approximately 60% of what it was forty years earlier. Guatemala showed the lowest rate of decrease in rural population relative to total population, with an overall decrease of 10% over the entire period. The countries in 2001 with the highest percentage of rural population were the later-developing and less population-dense Guatemala and Honduras, and the lowest two were the earlier industrialized El Salvador and Costa Rica. However, the decrease in rural population in El Salvador occurred mostly between 1991 and 2001, while Costa Rica has experienced a steadily declining rural population over the past 40 years.

The rate of increase in the consumption of fertilizers per ha far outpaced the rate of increase in agricultural production in the region. Table 6.5 provides a breakdown of fertilizer use by country, indicating that the total consumption of fertilizers per ha in 2001 was more than six times the region's 1961 level. Costa Rica, Honduras, and Guatemala had the highest fertilizer per ha consumption in 2001, respectively. The country that experienced the highest percentage increase of fertilizer use per ha was Honduras, whose 2001 level had increased by twenty-five times its 1961 level. Honduras also shows the smallest decrease in forest cover between 1961 and 2001 (11%), showing that agricultural production (which increased almost 300% between 1961 and 2001) occurred without a substantial reduction in forest cover when compared to other Central American countries, most likely attributable to it being the largest user of fertilizer in the region. Costa Rica, whose fertilizer use per ha increased more than five times, had the third smallest decrease in forest cover (45%) between 1961 and 2001, after Honduras (11%) and Panama (40%). The other Central American countries (El Salvador, Guatemala, Nicaragua, and Panama) combined level of fertilizer use per ha of arable and permanently cropped land in 2001 was more than four times their combined 1961 level.

Table 6.4 Share of rural population by year and country (%)

Country	1961	1971	1981	1991	2001
Costa Rica	65.7	60.5	52.2	45.8	40.5
El Salvador	61.2	60.3	55.4	50.0	38.5
Guatemala	67.2	64.2	62.5	61.8	60.1
Honduras	77.1	70.4	64.6	57.1	46.3
Nicaragua	60.1	52.4	49.4	46.7	43.5
Panama	58.2	52.0	49.2	46.0	43.5
Total	65.6	61.4	57.4	53.7	48.0

Table 6.5 Fertilizer use on land cropped by year and country (kg/ha)

Country	1961	1971	1981	1991	2001
Costa Rica	39	115	142	226	244
El Salvador	32	121	122	94	80
Guatemala	10	16	51	80	96
Honduras	4	18	16	19	106
Nicaragua	3	22	45	23	10
Panama	9	43	54	39	42
Regional use	12	40	56	61	77
Average	16	56	72	80	96

DISCUSSION AND CONCLUSION

This chapter introduced the topic of limits to deforestation from an analysis of trade-offs between agricultural sustainability and deforestation in Central America, with a discussion of current trends and an examination of changes in a handful of key variables during the previous four decades. Following an exploration of the importance of sustainable agriculture in Central America, we analyzed changes in production for the region over the previous four decades at the expense of forests relative to intensification inputs. We will now briefly review the major findings before discussing the potential of future food production dynamics to increase production while preventing further substantial forest conversion in the region.

Agricultural production doubled in Central America from 1961 to 2001. As we expected, the greater proportion of this increase came from agricultural intensification, rather than from the expansion of agricultural land or labour investments. Extensification was greatest in the countries of most abundant remaining forestland, Guatemala and Costa Rica. However, intensification in the form of fertilizer usage increased dramatically in all nations and was highest in the nations of greatest rural development and most earnest export agriculture, Costa Rica and El Salvador. These countries also experienced the most rapid urbanization and had the smallest proportion of rural dwellers in 2001, suggesting that agricultural output per labourer, due to capital investments in mechanization and chemical inputs, increased disproportionately to agricultural output in these countries. Lastly, the more developed countries such as Costa Rica and El Salvador manifested a combination of earlier urbanization and increased agricultural intensification compared with less developed countries, such as Guatemala and Honduras.

Although production has increased, there are several patterns that raise doubts about the sustainability of recent trends. Intensification in the form of fertilizer use grew several times to assist in a mere doubling of food production. Such diminishing returns augur poorly for the sustainability of current systems. Although inputs have compensated for a declining rural labour pool, as rural families continue to migrate to cities, socio-economic levels should rise, along with demand for meat. This will tax rural production systems further as livestock production is a much less efficient land use than crop production. This trend is sobering given the rapidly diminishing forestland in the region, and thus, the ever-decreasing potential to increase production through agricultural extensification. Land extensification in the next decades is expected to contribute to some important environmental problems in the region, such as the loss of biodiversity, soil degradation (as land extensification occurs into fragile areas), and regional climate change.

Thus, future scenarios point to growing conflicts between regional production to meet the demands of a growing population and international markets, and mitigation initiatives regarding conservation of forests and other natural resources (soil, water and the regional biodiversity). Increasing global and local climate change is also likely to affect food supply and productivity, with important implications on the sustainability of agricultural systems. In this sense, policies will be needed to focus on sustainable development strategies that integrate human, environment, and food sustainability in agricultural systems.

Future research will need to further probe trade-offs between the means to production and the implications not only for food production, but also for the sustainability of natural environments and rural livelihoods. Further, more detailed measures of the means to production need to be examined. For example, our measure of agricultural intensification examines fertilizers, but not the use of pesticides, herbicides, mechanization, and irrigation - and their impacts on the environment. Such considerations would add to the depth of analysis on agricultural intensification and its environmental impacts. Lastly, trade-offs between labour, land, and capital intensification on the one hand and extensification and reduction in forest cover on the other hand need to be examined explicitly in terms of percent changes in one factor relative to changes in another. Only then can estimates of relative efficiency of returns to inputs be examined in the context of agricultural sustainability and its impacts on people and the environment.

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