1. Introduction

Recent reports of elevated rates of tropical deforestation in Brazil during the mid-1990s, coupled with the pessimistic report about tropical forests issued by the European Community's Research Centre in 1998, underline the urgency of the search for a policy solution to the problem. In this context, the Borlaug hypothesis, named after its most famous exponent, merits detailed examination. Norman Borlaug and others have asserted that significant increases in the land productivity of agricultural commodities would solve the problem of tropical deforestation by reducing the need to expand the area of cultivated land as demand for crops increases (World Resources Institute, 1986; Rudel with Horowitz, 1993; Southgate, 1998).

The simplicity of Borlaug's argument makes it appealing. It also gains in stature because it draws upon the most coherent body of theory in social science, microeconomics, to make its essential point. The theory also has clear policy implications: to reduce tropical deforestation, governments and international organizations should greatly expand their programmes of research into the land productivity of crops grown in the tropical biome. Despite these attractive features, the theory has not been tested empirically. Under these circumstances, a historical study of changes in crop yields and forest cover in the American South between 1935 and 1975 may provide useful insights about the validity of the Borlaug hypothesis.

Examining forest-cover dynamics in the southern USA, with an eye to the lessons that it might have for forest-cover dynamics in the tropics, may seem like a far-fetched idea, but for two reasons it is not. First, because the Borlaug hypothesis concerns a process of technological innovation and diffusion among thousands of farmers, followed by a period of forest regrowth, any assessment of it must entail a historical study stretching out over several decades. Very few, if any, of the countries in the tropical biome contain the detailed historical records on changes in forest cover that would be necessary to follow changes in the acreage devoted to specific crops over several decades. In contrast, the data on southern US forest cover and its driving forces are complete enough to conduct a fairly conclusive test of the hypothesis.

Secondly, the American South in 1930, at the beginning of the period under study, resembled contemporary developing countries in several crucial respects (Vance, 1932). The south-eastern USA contains red clay soils, much like those commonly found in large parts of the Amazon basin (Sanchez, 1976). Despite the poor soils, a large majority of the regional population, black and white, earned a living from agriculture, usually on small farms devoted to cotton cultivation. Four out of five farmers worked land that they did not own, usually as sharecroppers. They were poor. Farmers in the south-eastern cotton-growing states averaged $143 in income per year from their crops between 1924 and 1929 ($637 in 1989 dollars). Farmers had a commercial orientation, producing cash crops, such as cotton and tobacco, for global markets. In 10-15% of the agricultural districts, farmers had a subsistence orientation, consuming more of their harvests than they sold (Rudel and Fu, 1996: 813). Eleven per cent of the regional population was illiterate in 1930 (Odum, 1936; Johnson et al., 1941). In talking about the South's position in the national economy, analysts anticipated the parlance of contemporary world systems theorists, using terms like 'peripheral' to describe the South's position. Within the USA, the South was a colony of the North (Vance, 1932: 470-481). As a noted regional geographer put it,

*The South is the part of the United States which is most similar to the rest of the world, and the plantation regions are the areas of the South which are most comparable to the new nations that inherited plantation economies. In certain respects the lower Piedmont, the Black Belt, the Loess Plains, and the alluvial Mississippi Valley have more in common with the former colonies of the Caribbean and Central and South America than with the metropolitan United States.*

(Aiken, 1998: 363-364)

Certainly the argument that the experience of the American South between 1935 and 1975 resembles that of contemporary developing countries can be pushed too far. The transportation network of the region - its roads, railways and canals - had been well developed through decades of internal improvements since the Civil War. Unlike many contemporary developing countries, the South had a system of secure property rights in land. The magnitude of industrial job creation in northern metropolitan areas prompted heavy out-migration from the South between 1935 and 1975. Throughout this period, the state supported agricultural production through price supports, subsidized credit and conservation set-aside programmes. None of these factors have historical
parallels in developing countries. Nevertheless, the exceptional quality of the data and the existence of some historical parallels between the South and places in the tropical biome argue for using the South as a test case for examining the validity of the Borlaug hypothesis.

To investigate the effect of increases in the land productivity of crops on forest cover, I bring together data on the prevalence of particular crops in counties, trends in the land productivity of those crops and trends in forest cover in those counties. Assuming little change in demand for the different crops, more fields should have reverted to forests in places with agricultural economics organized around the crops that recorded the greatest gains in agricultural productivity between 1935 and 1975.

Three processes of technological change influenced trends in agricultural productivity in Southern agriculture between 1935 and 1975. First, publicly financed land-improvement projects, in particular the drainage of wetlands, changed the land base available to farmers, giving them access to more fertile lands. Secondly, subsidized fertilizer production and, after 1955, the introduction of herbicides in cotton cultivation elevated yields per acre (Aiken, 1998: 109). Thirdly, agribusinesses promoted the mechanization of agriculture, through the introduction of first tractors and later harvesters. The last trend reduced the amount of labour and increased the amount of capital utilized per hectare in Southern agriculture. Not surprisingly, this trend led to a considerable increase in the scale of agricultural operations. In the following analyses, measures of regional soil resources provide a proxy measure for wetlands reclamation and expenditures for fertilizers at the outset of the period measure fertilizer use. I do not have a good measure of the effects of mechanization on land productivity.

As controls in the analysis, I introduce additional data on the human capital of farmers, the size of nearby urban places and government policies. These variables embody plausible alternative explanations for the reforestation of the South during the middle decades of the 20th century. The human capital variable, illiteracy, expresses the idea that farmers with little human capital would face competitive disadvantages brought on by the advent of more scientific agriculture, which would eventually cause them to abandon their lands and allow their fields to revert to forest. In counties with sizeable urban communities, farmers could scale down their agricultural enterprises without completely abandoning them because farmers could more easily secure part-time employment in the non-farm sector. For this reason complete farm abandonment and reforestation should characterize remote rural counties more than counties with sizeable urban communities. The federal government, through several policy initiatives, most prominently the price support-conservation set-aside programme introduced in 1934 and the expansion of national forests during the 1930s, may have played an important role in the reforestation of the South. A multivariate analysis that includes these variables and the productivity variables in a single equation predicting trends in forest cover should tell us something about the relative magnitude of the agricultural productivity effect on forest cover.

2. Data, Variables and Measures

Counties are the units in the analyses reported below. The data on forest cover come from forest inventories conducted by the US Forest Service every 10 years, beginning in the 1930s. The data on crop productivity come from the US Department of Agriculture, and the data on soil resources come from a survey carried out during the 1930s by the Bureau of Agricultural Economics of the Department of Agriculture. The data for all other variables in the analyses come from the Statistical Atlas of Southern Counties (Johnson et al., 1941). The data sources and measures are listed in Table 4.1. Several of the measures reported in Table 4.1 require some explanation.

2.1. Changes in forest cover

I calculated the average annual rate of change in forest cover between 1935 and 1975 for approximately 800 counties in the southern USA. The data on forest cover come from successive forest surveys, conducted every 10 years, beginning in the 1930s, by the US Forest Service. The measurement techniques have evolved over the history of the forest survey from on-ground parallel-line surveys to aerial photos and then to satellite images. The change from on-ground to aerial photo methods does not appear to have biased the measures in a discernible way (Cruikshank and Evans, 1945).

Table 4.1. Data sources and measures

<table>
<thead>
<tr>
<th>Forest cover sources</th>
<th>Change in % per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest survey bulletins published by Southern forest</td>
<td></td>
</tr>
<tr>
<td>experiment stations, 1930s-1970s.</td>
<td></td>
</tr>
</tbody>
</table>
2.2. Land capability (% delta, % piedmont)

At the request of planners in the Department of Agriculture during the depression, C. Barnes and F. Marschner delineated agricultural regions in the USA. They brought together information on the physical geography of agricultural areas, their topography, their soils and their climate, and used this information to construct a map of the agricultural potential of different regions in the USA. In this exercise, the boundaries between regions became, in effect, boundaries between land capability classes. For example, a boundary separating the Mississippi delta from the sandy lands of southern Mississippi is in effect, a boundary separating a region with high land capability from a region with low land capability.

2.3. Land productivity

This variable measures the gains in yields per acre for the chief commercial crop in a county. Because there are only seven basic commercial crops grown in the South during this period, there are only seven possible values that this variable can assume in a county. Furthermore, the productivity gains reported here are averages for the entire USA, not just the South. While this circumstance creates measurement error for a crop like maize, which was grown extensively outside the South, there is little measurement error for most of the other crops (e.g. cotton, peanuts), because they are grown largely, and sometimes solely, in the South.

In the bivariate and multivariate analyses reported below, I use these variables and the others listed in Table 4.1 to explore the historical relationship between agricultural productivity and forest cover in the South. To avoid problems of simultaneity bias in the analyses, the explanatory variables precede the changes in forest cover or come from the first portion of the four-decade period in which I measure forest cover.

3. Findings

Between 1935 and 1975, forests expanded in extent across much of the south. Overall about 8% of the South's land area reverted to forest during this period (Rudel and Fu. 1996). Dramatic subregional variations marked the regional pattern of forest-cover change. As the map of forest-cover change in Fig. 4.1 suggests, some agricultural regions, such as the piedmont in the Carolinas, virtually disappeared, while others, such as the Mississippi delta, expanded vigorously. To paraphrase the foremost student of Southern land use, John Fraser...
Hart, the South during this period became 'a splendid laboratory for studying the birth and death of agricultural regions' (Hart. 1991: 276).

The patterns in the data arrayed in Table 4.2 suggest the degree to which these subregional patterns of agricultural expansion and decline correspond to differential rates of change in the land productivity of the crops that dominate in the agricultural economies of the different subregions. The table classifies rural Southern counties by their dominant cash crop and reports data on forest-cover change in those counties. Juxtaposed with the data on forest-cover change are data on changes in the agricultural economy of the dominant crop: increases in yields and in prices and changes in area planted in the USA. A comparison of the first four county types (cotton, tobacco, maize and peanut counties) with the last three county types (sugar cane, rice and orange counties) reveals a pattern that supports the Borlaug hypothesis. Those counties that saw the largest increases in the yields of their dominant crops (more than 109% over the 40-year period) showed greater gains in forest cover than those counties that showed lesser increases in yields per acre. The national patterns in acreage planted in the different crops suggest why the patterns of forest-cover change differ across the counties. Those crops with the largest increases in yields saw the largest declines in acreage planted. Interestingly, there is no apparent relationship between trends in the prices of agricultural commodities, productivity increases and reforestation during the 40-year period.


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>+5.32</td>
<td>+185</td>
<td>-57</td>
<td>+362.6</td>
</tr>
<tr>
<td>Tobacco</td>
<td>+14.20</td>
<td>+110</td>
<td>-38</td>
<td>+390.5</td>
</tr>
<tr>
<td>Maize</td>
<td>+11.85</td>
<td>+206</td>
<td>-33</td>
<td>+209.0</td>
</tr>
</tbody>
</table>
Figure 4.2 reports the results of the multivariate analyses, and it provides more conclusive evidence about the influence of agricultural productivity variables on the pattern of forest-cover change in the South. With the exception of the path from yield increases to changes in crop area to reforestation. Fig. 4.2 presents a simple inventory of causes regressed against the change in forest cover in a county over a 40-year period. The residuals are normally distributed and the levels of multicollinearity are low. Deletion of outliers produces some modest changes in the overall variance explained, but it does not change the relative explanatory strength of the different predictors of the reforestation rate in a county.

The most accurate predictor of reforestation rates, forest cover in a county in 1935, has an artefactual element to it. The highest rates of reforestation between 1935 and 1975 tended to occur in the counties with the lowest levels of forest cover in 1935, presumably because these counties had the most land that could be reforested. Land capability appears to have been an important factor in reforestation, because % piedmont (low land capability) and % delta (high land capability) are strong predictors of the reforestation rate. Human capital variables, loosely expressed here as the proportion of a county's population that is literate, the proportion of farmers engaged in subsistence agriculture and the proportion of the county's population living in its largest urban place, also exercised an important influence on reforestation rates. A government policy of expanding the size of national forests through the purchase of marginal agricultural lands made a direct contribution to the reforestation of the region. Finally, several technological changes associated with the Borlaug hypothesis appear to have played an important role in the reforestation of the South. Where farmers used more fertilizer in 1930, reforestation occurred at higher rates in subsequent decades, presumably because, with the aid of fertilizers, they concentrated production on fewer acres. As depicted in Fig. 4.2, large yield increases in particular crops led to large declines in the amount of land devoted to the cultivation of that crop, and these declines in acreage increased the rate of reforestation in a county. This sequence of events conforms to the logic of the Borlaug hypothesis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Trend</th>
<th>Coefficient</th>
<th>Trend</th>
<th>Coefficient</th>
<th>Trend</th>
<th>Coefficient</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanuts</td>
<td>+20.06</td>
<td>+116</td>
<td>-40</td>
<td>+516.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar cane</td>
<td>+3.16</td>
<td>+108</td>
<td>+112</td>
<td>+441.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>-3.56</td>
<td>+96</td>
<td>+123</td>
<td>+379.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oranges</td>
<td>-24.16</td>
<td>+88</td>
<td>-60</td>
<td>+149.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 4.2. Path diagram: determinants of Southern reforestation, 1935-1975. Numbers are standardized coefficients, n =777, adjusted. R²= 0.594, P values, * < 0.05, ** < 0.01, ***< 0.0001**

4. Discussion

Does the Southern experience with increasing agricultural productivity and forest-cover change offer lessons for how rising crop yields might curb forest loss in tropical biomes? Certainly, the influence of the American state on forest-cover trends between 1935 and 1975 seems improbable in the current political context of most countries in the tropics. The American state launched more programmes that affected forests than the contemporary neoliberal states of the developing world will ever do. Some of the state's programmes probably
had only small effects. Price-support programmes enabled some farmers on marginal lands to remain on their land for a longer period than they would have otherwise. In this sense, the price-support and acreage-control programmes probably slowed the pace of change, rather than reversing its direction (Hart, 1978: 512). The plan for expanding the national forests through the purchase of marginal agricultural lands ensured that some lands, by becoming part of a national forest, reverted to forest. Arguably, these lands would have reverted to forest in any case. The Tennessee Valley Authority's celebrated reforestation programme had little impact on regional land cover (Rudel. 1995).

Other federal programmes, in particular the work of the Army Corps of Engineers, had an important impact on land-cover change. In the 19th and early 20th century, settlers cleared land for farming in the South's upland, but they avoided the low-lying, alluvial land in the Mississippi River delta and along the Gulf coast. The soil was very fertile, but periodic floods and difficulties with drainage prevented agricultural expansion into these areas, and they remained covered with hardwood forests, containing much high-quality wood. In the second half of the 19th century, local groups began to build levees in an effort to control floods along the Mississippi. Alarmed by the damage wrought by these floods and pressured by local lobbying groups, federal legislators assumed half of the costs of levee construction in 1916, and in 1928, after the particularly disastrous flood of 1927, the federal government assumed the entire cost of levee construction (O'Neill, 1998). A 1944 amendment to the 1928 act extended federal assistance to drainage of lands behind the levees. With these mandates, the Army Corps of Engineers began an ambitious programme of public works in the Mississippi delta and along the Gulf coast during the 1930s, building levees and later draining swamps (Ferguson, 1940; Harrison, 1951: McPhee, 1986: US Army Corps of Engineers, 1989).

With the low-lying lands secured from floods, landowners moved quickly to harvest the valuable timber and plant soybeans in the cleared fields (Sternitzke and Christopher. 1970). The flat, fertile and uniform fields were ideal for the highly mechanized agricultural techniques used in the cultivation of soybeans. The contrasting trends in forest cover in Table 4.3 between cotton counties inside and outside the Mississippi delta testify to the effects of government flood-control programmes on forest cover in lowland regions. In the sugar-cane-growing regions of Louisiana, a similar but less pronounced pattern developed, with landowners growing cane in the protected areas behind the levees along the Atchafalaya River (Hart, 1978: 512).

Table 4.3. Natural land-use areas and forest-cover change in cotton-growing counties, 1935-1975* (based on Barnes and Marschner, 1933; Forest Inventories, US Forest Service, 1935-1965).

<table>
<thead>
<tr>
<th></th>
<th>Forest cover, 1935 (% of land area)</th>
<th>Forest cover, 1975 (% of land area)</th>
<th>Forest-cover change (% per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside the Mississippi delta</td>
<td>53.39</td>
<td>63.03</td>
<td>+0.245</td>
</tr>
<tr>
<td>Inside the Mississippi delta</td>
<td>53.31</td>
<td>38.89</td>
<td>-0.328</td>
</tr>
</tbody>
</table>

*Number of counties: 1935 = 488, 1965 = 509.

The rapid growth of soybean cultivation in the alluvial lowlands of the South stems in part from the development of new markets for soybean-based animal feeds. A similar set of developments in consumer markets explains the rapid expansion of cultivated acreage in the citrus-producing areas of central Florida between 1935 and 1975 (see Table 4.2). The model in Fig. 4.2 does not incorporate the effects of changes in markets and consumer tastes on forest-cover trends, but clearly they had a significant effect. The increasing returns to human capital in cities also played an important, albeit indirect, role in the pattern of reforestation. The significance of the illiteracy, subsistence farming and urban place variables in the models testify to the rapidly increasing returns to human capital in urban areas, in the form of either new jobs or higher wages (Ruttan, 1984: 151-152). Rural poverty pushed and urban economic growth pulled smallholders off their farms and hastened the return of their fields to forests.

The decline in the agricultural labour force spurred mechanization in Southern agriculture, which, in turn, encouraged land abandonment in areas of low land capability. When farm workers left the land, plantation owners keep the flat, fertile lands of the delta in production by purchasing tractors and harvesters to replace field hands. Farmers who worked the more accentuated terrain of the Piedmont did not think that they could use machines to replace labour on these lands (Aiken, 1998: 118-119). Given the more impoverished soils in the piedmont, farmers faced with the problem of labour scarcity in this setting frequently abandoned farming, other farmers in these regions, faced with declining yields, did not need the spur of labour scarcity to abandon their lands. Because the most capable agricultural lands in the South are concentrated in islands or strips of land surrounded by more extensive areas of less fertile lands, the landscape in the American South began, by the 1970s, to appear like islands of intensive agriculture in a sea of forested and reforested land.
While the findings in Fig. 4.2 provide general support for the Borlaug hypothesis, three issues remain unclear. First, the mid-20th century saw a rapid expansion of cotton cultivation outside the American South, in particular in the western USA. How did the expansion of production in these competing areas affect land abandonment in the South? The Reclamation Act of 1902 authorized the federal government to develop irrigation systems for agriculture in the American West (Lee, 1980). After the Second World War, the state of California supplemented the federal programme with its Central Valley Project. In California, cotton became one of the crops of choice for farmers on these irrigated lands. The yields per acre on these fertile, irrigated fields averaged more than twice the national average for cotton throughout the 1935-1975 period, and California's share of national cotton acreage grew from less than 1% in 1935 to approximately 10% in 1975 (Scheuring, 1983: 117; USDA, 1999). By 1975, cotton had become the most valuable field crop produced in California; only Texas produced more cotton than California.

Several economists have claimed that federal programmes for irrigating the West resulted in the abandonment of 6 to 18 million acres of land in the eastern USA (Howe and Easter, 1971). The growth of cotton cultivation on irrigated lands in California and the decline of rain-fed cotton lands in the South would appear to be a case in point. Historical data on acreage in cotton in the two regions do not, however, support the idea of a simple substitution of western cotton lands for eastern cotton lands. Most of the reforestation on Southern cotton lands begins between 1935 and 1945, a decade in which cotton acreage in California did not increase. The significant increases in California acreage occur during the 1945-1955 and 1969-1975 periods, but they do not coincide with or precipitate significant losses in cotton acreage in the South in a way that is clearly visible. In sum, the increase in cotton cultivation in the American West probably contributed to the abandonment of cotton lands in the South, but the magnitude of this effect on forest-cover dynamics cannot have been particularly large, because it is not apparent in the historical data (Scheuring, 1983: 128; USDA, 1999).

Secondly, questions could be raised about the magnitude of the cause-effect link between yield increases and forest recovery in the South. A comparison of the explanatory power of the different groups of variables in Fig. 4.2 makes it clear that the effects of agricultural productivity on forest recovery were not trivial. The two agricultural productivity variables explain 6% of the total variation in the Fig. 4.2 equation for reforestation, compared with 4.4% for the two human capital variables and 2.8% for the land capability variables. The timing of the reforestation sheds additional light on the influence that increases in agricultural productivity had on reforestation. Virtually all of the reforestation occurred during the first 20 years, 1935 to 1955, of the 40-year period under examination. A historical conjuncture of three watershed events, the Depression, the New Deal and the Second World War, pushed reforestation during this period. Low commodity prices encouraged farmers to abandon marginally productive lands. The recently established Tennessee Valley Authority made low-cost fertilizers widely available, which enabled farmers to concentrate their production on fewer acres. War-induced demands for military service and manufacturing workers spurred the departure of farm workers and increased the use of farm machinery on the flat, fertile soils of the Mississippi delta. The departure of the farm Labour force during the war caused farmers in areas of low land capability to allow their lands to remain idle. The poverty and illiteracy of farmers and farm workers posed additional obstacles to the acquisition of credit and the adoption of land-saving technologies, such as fertilizers. In this manner, technological changes interacted with other historical events to produce widespread land abandonment and reforestation in the South. In sum, a con-juncture of events, of which agricultural productivity increase is an important component, contributed to the recovery of the South's forests after 1935.

Could productivity increases alone have produced the widespread conversion of agricultural lands into forest; The answer to this counterfactual question is clearly no, at least in the case of the American South. The related events outlined above, which included increases in land productivity, produced the large-scale conversion of farmlands into forests.

Thirdly, the absence of an obvious relationship between changes in the prices of agricultural commodities during this period and reforestation raises questions, because the Borlaug effect reputedly works through changes in prices. Rapid increases in yields per hectare lower the prices of agricultural commodities, which, in turn, encourage farmers to abandon marginal agricultural lands. The political and economic dynamics of agricultural price-support programmes may explain why a causal path from yield increases to price changes and then to reforestation does not exist. Because the federal government intervened to maintain the price of an agricultural commodity when it was in oversupply, productivity gains did not necessarily lead to declines in a commodity's price, but they did lead to an increase in government price-support expenditures. In reaction, government officials may have pushed set-aside programmes more vigorously, in an effort to reduce the government's price-support expenditures. While good historical data to substantiate these claims are scarce, a sequence of events like this one would explain why land productivity changes, but not price changes, associate positively with rates of reforestation.
5. Conclusion: Implications for Patterns of Change in Tropical Forest Cover

In one respect, the American South represents the 'least Rely case' (Eckstein, 1975) in which to observe a connection between increases in crop yields, declines in acreage planted and increases in forest cover. The effects of New Deal flood-control programmes, national forest purchases, price supports and acreage controls influenced farmers' decisions about the amount of land to cultivate and, in so doing, these programmes should have obscured the relationship between crop yields and the amount of cultivated land. Despite these dampening effects, crop yield increases did appear to facilitate forest recovery in the South. In the more neoliberal political environments of contemporary developing countries, one should observe a stronger relationship between changes in crop yields and acreage planted.

A second consideration would suggest that the Southern agricultural experience should provide ample evidence of a crop yield-acreage planted connection. The processes of industrialization in American metropolitan areas after 1939 created very large numbers of jobs, which pulled people off farms in a decisive way. When people left the farms in the 1930s, 1940s and 1950s, they usually found full-time employment and did not go back to the farm. The industrialization impulse in most countries in the tropical biome is weaker; urbanization occurs, but the increase in the number of full-time jobs is smaller relative to the number of migrants than it was in the USA earlier in the century. Under these conditions of 'overurbanization', rural-urban migrants often retain a landholding in rural areas and continue to farm it for subsistence purposes. Because acreage devoted to subsistence cultivation should not be subject to the same crop yield-acreage planted dynamic as acreage producing commodities for the market, an increase in crop yields could produce a muted response in acreage planted, especially during difficult economic periods. People will continue to plant on marginal lands for security reasons, even after calculations of marginal productivity would suggest land abandonment. Because mid-century Americans had a viable economic alternative to agriculture in urban labour markets, they abandoned agriculture on marginal lands more readily when increases in crop yields increased the competitive pressures on marginal farmers. For this reason, we would expect to see a response to crop yield increases in the acreage planted in the American South; it did appear, but only on the marginal lands of the region.

One of the most incontrovertible findings from this investigation of the crop yield-acreage planted relationship involves the way in which the land capability variables mediate the relationship between increases in crop yields and trends in forest cover. The geography of soil fertility influences the elasticity of the acreage-planted variable in response to changes in crop yields. Figure 4.3 portrays this relationship. If fertile soils comprise only a small portion of a region, as in region A in Fig. 4.3, and as much as 67% of the region is cultivated, then an increase in crop yields would, by lowering the price of the agricultural commodity, put the farmers on marginal soils under such competitive pressure that they might decide to allow the land to revert to forest while they seek economic alternatives elsewhere. This land-abandonment response is especially likely if the government has imposed strict acreage restrictions on a particular crop, as, for instance, the American government did on tobacco. Under these circumstances, farmers only cultivate their best lands. This sequence of events approximates what happened in Puerto Rico after 1950, when competitive pressures in global markets for coffee, sugar cane and tobacco, along with other factors, encouraged smallholders to abandon steep hillside farms. Forests increased from 10% to 37% of the land area on the island between 1950 and 1990 (Rudel et al., 2000). In contrast, if fertile lands are distributed as in region B in Fig. 4.3, the increase in crop yields may not produce much of a decline in acreage planted. The large majority of producers are more hard-pressed under the new, more land-productive conditions, but few of them are forced out of the business because more capable lands are more widely distributed, so little land reverts to forest.
These scenarios conform to the familiar geography of forest transitions. As deforestation gives way to reforestation, the cultivated areas retreat to the lands with the most agricultural potential (Mather and Needle, 1998). Answers to questions about the likelihood of this type of transition in tropical biomes probably depend on the geographical distribution of land capability in tropical places. In her work on the Amazon basin, Betty Meggers (1996) drew a sharp distinction between the small area of fertile lands in the *varzea* and the large area of relatively barren lands in the *tierra firme*. Her critics (Whitehead, 1993) have argued for a more variegated understanding of Amazonian soil resources, implying that pockets of fertile land exist in many locales. A resolution of this debate about land capability in the tropics should give us a more precise idea about the conservation potential of increases in the yields per acre of tropical crops. The larger the differences between fertile and infertile areas in their productivity and the more limited the extent of the fertile areas, the more likely it is that increases in yields will produce significant conservation gains.

**Notes**

1. It would have been useful to include data on the extent of the conservation set-aside programme in each county, but I could not find these data.

2. I classified counties according to the land area planted in different cash crops at the time of the 1930 census. If a county had 45% of its cultivated area in cotton and 30% in maize - a common combination - it was classified as a cotton county. Quite frequently, more acreage was planted in maize than in any other crop, but much of this maize was being grown for subsistence purposes, to feed people or pigs. In those instances where a county reported a considerable amount of acreage (more than 10%) in a cash crop, such as tobacco, cotton or peanuts, the county was defined as a tobacco, cotton, or peanut county, if there was no important cash crop grown in the county and farmers in the county grew a great deal of maize. I defined it as a maize county.

3. Were black and white tenant farmers displaced by machines; Some were and some were not. The widespread adoption of tractors in Southern agriculture begins in 1935, and clearly many tenants evicted after that date were 'tractored out' (Aiken, 1998: 119-132). Black and white tenants begin leaving plantations during the 1920s, well before the introduction of tractors. Others were evicted in 1933/34 by plantation owners, who did not want to share price-support payments with tenants after the passage of the Agricultural Adjustment Act.

4. Later, farmers learned to use machinery on these lands, but only after introducing land improvements, such as terracing (Aiken, 1998: 118).

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Control Mississippi River Floods. Mississippi Agricultural Experiment Station, Stoneville, Mississippi.


