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Tree farms: Driving forces and regional patterns in the global expansion of forest plantations

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ABSTRACT

People have planted trees in rural places with increasing frequency during the past two decades, but the circumstances in which they plant and the social forces inducing them to plant remain unclear. While forests that produce wood for industrial uses comprise an increasing number of the plantations, most of the growth has occurred in Asia where plantations that produce wood for local consumption remain important. Explanations for these trends take economic, political, and human ecological forms. Growth in urban and global markets for forest products, coupled with rural to urban migration, may spur the conversion of fields into tree farms. Government programs also stimulate tree planting. These programs occur frequently in nations with high population densities. Quantitative, cross-national analyses suggest that these forces combine in regionally distinctive ways to promote the expansion of forest plantations. In Africa and Asia plantations have expanded most rapidly in nations with densely populated rural districts, rural to urban migration, and government policies that promote tree planting. In the Americas and Oceania plantations have expanded rapidly in countries with relatively stable rural populations, low densities, and extensive tracts of land in pasture. If, as anticipated, the growing concern with global warming spurs further expansion in forest plantations in an effort to sequester carbon, questions about their social and ecological effects should become more pressing.

Introduction

Landowners who decide to plant trees engage in an unusual form of agriculture. Compared to row crops, planted trees grow better on sloped land, require significantly less labor, and yield very little financial return for the first 7 or 8 years after planting (Bentley, 1989). For these reasons landowners only create tree farms under a select set of conditions. Forest plantations currently make up only about 5% of the world's forests, but they have been increasing rapidly in extent. Between 1980 and 2000 the extent of forest plantations increased sevenfold in developing countries (Del Lungo et al., 2001). A wide variety of landholders have established plantations. Smallholders in Africa created woodlots behind their houses (Fortmann and Bruce, 1988; Tiffen et al., 1994). Corporations have planted extensive tree farms in Australia, North America, and South America (Marchak, 1995; Barlow and Cocklin, 2003). Villages in mainland Southeast Asia have planted trees in nearby uplands (Muller and Zeller, 2002), and state agencies have planted trees on degraded lands in South Asia (Guha et al., 1984). This diverse assemblage of forest plantation owners may be changing. Since 1980 large plantations producing wood for industrial purposes have grown especially rapidly (Del Lungo et al., 2001).

As these people planted orderly rows of trees on more land during the last two decades of the 20th century, controversies over the effects of tree farms on rural societies and ecologies grew louder. Advocates for tree farms (Victor and Ausubel, 2000) pointed to the very high rates of wood production achieved on model plantations in the tropics like the Aracruz holding in Brazil (Marchak, 1995) and argued that these 'fastwood' farms can deliver important economic and environmental services. By meeting market demands for paper products from pulpwood, forest plantations lower the price for pulpwood and, in so doing, reduce the economic incentives to log natural forests (Kohlin and Parks, 2001). The rapid rates of growth achieved on tropical tree plantations also enable them to sequester appreciable amounts of carbon, enough that, if planted on a large enough scale, tropical tree farms could offset a substantial amount of the carbon emissions from the consumption of fossil fuels (Gibbard et al., 2005; Righelato and Spracklen, 2007).

Critics see forest plantations as vehicles through which 19th century colonial officers (Peluso, 1992; Guha, 2000); and more recently corporate officials (Potter and Lee, 1998; Rohter, 2004) have deprived poor rural peoples of access to lands and livelihoods. The plantations also despoil the local ecology through the introduction of fast growing exotic species like *Eucalyptus rostrata* and

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Pinus caribaea that, among other things, absorb so much water that plantations of these species markedly reduce local stream flows (Cossalter and Pye-Smith, 2003). Since 2000 people have begun to voice an additional set of concerns about the ecological effects of planting transgenic trees in plantations (Petermann et al., 2006).

These debates about the merits and demerits of forest plantations, while valuable, leave unanswered some important questions. The literature focuses on high profile plantations in Brazil, Chile, and Indonesia, but the representativeness of these plantations and the associated political conflicts remains open to question. The spatial and social characteristics of forest plantation expansion can best be appreciated through global scale analyses like the one offered here. Statistical analyses of these patterns provide an opportunity to assess explanations for plantation expansion, one that emphasizes the economic and demographic forces that accompany urbanization, another that focuses on political initiatives to increase environmental services by expanding the size of forests, and a third one that emphases high population densities in rural areas. To answer these empirical and theoretical questions, this paper presents a cross-sectional analysis of the extent of forest plantations in 2005 followed by an analysis of changes in the extent of forest plantations between 1990 and 2005.

Theory

Social scientists have offered several different explanations for the increasing extent of forest plantations. Economists theorize that the recent growth in forest plantations of all types stems from increases in the scarcity of forest products throughout the world (Foster and Rosenzweig, 2003). At least one body of theory, referred to as forest transition theory, draws upon geography and sociology as well as economics to explain the recent expansion in forest plantations. Forest transition theory would attribute the expansion of forest plantations to shifts in market forces that occur with the urbanization of societies and the globalization of forest products markets (Rudel et al., 2005). The concentration of people in cities raises their incomes and increases their expenditures on wood products, so markets for forest products grow. The accompanying rural to urban migration makes farm labor more expensive and compels farmers to reduce the amount of land that they farm. Farmers respond to these labor and forest product scarcities by converting their least productive fields, often on sloped lands, into tree farms which require less labor than row crops (Mather and Needle, 1998; Schirmer et al., 2005). In instances where the children have left a farm, the conversion from crops to trees may not occur until the land passes into the hands of a younger generation that does not want to farm. In this sense the decline in the family farm presages the rise of the forest plantation (Neumann et al., 2007).

Where rural to urban migration has not 'emptied out' rural areas, the creation of forest plantations often leads to conflict. Nineteenth century colonial regimes expropriated lands held by smallholders in order to secure supplies of wood and induced widespread resistance (Peluso, 1992; Guha, 2000). More recently, when a regional development agency induced smallholders in Lesotho to fence off some grazing land for woodlots in the 1980s, pastoralists tore down the fences and uprooted the trees (Ferguson, 1990, pp. 242–243). Some of the most protracted conflicts over forest plantations in Latin America have involved corporations and Amerindians like the Mapuche of southern Chile (Rohter, 2004). Amerindians have enjoyed particularly rapid rates of natural increase in Latin America over the past two decades and they are less likely to migrate to urban areas than their *mestizo* neighbors (McSweeney and Arps, 2005). Under these circumstances, forest industries covet large tracks of land because they intend to take advantage of economies of scale in producing wood for large, oftentimes, global markets. Amerindians still use these lands, and conflict ensues. More generally, forest transition theory predicts that societies with streams of rural to urban migrants and growing numbers of prosperous urban consumers will create more extensive tree plantations.

While the urbanization–globalization hypothesis explains the expansion of forest plantations largely in terms of market mechanisms involving individuals, another line of theorizing focuses on government actions and the aggregated environmental effects of forest plantations. Not surprisingly, the driving forces in this explanation are political. Government officials decide that the ecosystem services provided by forests are important to the well being of the society, and they create programs to expand the size of forests by planting trees. The most commonly cited environmental service provided by forests involves flood control. Trees absorb water, so, at least in theory, when the headwaters region of a largely forested river basin experiences heavy rains, the trees absorb the water and reduce the likelihood of downstream flooding. When the rains fall on cleared land, the water runs off of it, and the increased volume of runoff causes flooding downstream (Bradshaw et al., 2007). In the aftermath of damaging floods politicians want to do something, so they have put programs in place to increase forest cover. If the new programs expand local supplies of wood and reduce a country's timber imports, so much the better from the politicians' point of view.

Government-led programs of tree planting have occurred in a variety of contexts. The Chinese government accelerated already massive efforts at tree planting in the aftermath of the great Yangtze River floods in the late 1990s (Mather, 2007). The federal government in the United States initiated a Shelterbelt Project of planted trees to forestall further dust storms in the Great Plains during the 1930s (Droze, 1977). Non-governmental organizations (NGOs) with similar goals of environmental improvement frequently complement and strengthen these state led efforts at landscape transformation (Brechin, 1997). This sequence of events may take a new form in the 21st century if and when heads of state decide that they want to take advantage of the carbon sequestering environmental services provided by planted forests in order to combat global warming.

A final line of theorizing about the changing incidence of forest plantations emphasizes variations in the human ecology of rural areas. In some places like central China high population densities in rural areas have created pressures to eliminate forests for cropped land (Williams, 2006, pp. 310–311). Alternatively, arid conditions may have in some places caused cultivators to eliminate forests in the few places where they could grow naturally. Under these circumstances wood products grow scarce, and people may respond by planting trees. These processes may explain why the longest lived government assisted tree planting programs often occur in countries with arid regions, like Spain or countries in the Sahel (Brechin, 1997). This line of reasoning explains differential rates of plantation expansion as the outcome of coupled human–natural situations that vary both regionally and historically.

Data collected by officials at the Food and Agricultural Organization of the United Nation (FAO) on the changing extent of forest plantations across nations makes it possible to assess, through statistical analyses, the merits of the market-based urbanization–industrialization explanation, the more political environmental services explanation, and the human ecological explanation for recent increases in the extent of forest plantations. The methods of analysis and results are outlined below.

Materials and methods

The data for the following analysis comes from the Food and Agricultural Organization of the United Nations. Beginning in 1990, FAO officials began requesting data on the extent of planted forests from officials in each country. They repeated their requests for the Forest Resource Assessments of 2000 and 2005. To make the data comparable, FAO officials established a common definition for use in estimating the extent of planted forests (FAO, 2004). For each country they conducted a detailed forest inventory and examined changes in national forest policy. I use these data to measure changes in the extent of forest plantations and changes in forest policy pertaining to the plantations. Two features skew estimates from the FAO data in non-random ways. First, the FAO definition of forest plantations includes larger planted areas (>.5 hectares), but misses many small woodlots behind smallholders' homes. This omission leads, most likely, to underestimates of the extent of planted forests in Africa because woodlots comprise a large proportion of the planted forests, particularly in Western and Southern Africa (Holmgren et al., 1994; Tiffen et al., 1994). Second, forest ecology affects the extent of forest plantations in some places. Countries with humid forest areas, like Canada, tend to have fewer plantations because natural regeneration repopulates many cutover areas. Foresters in these countries often manage 'modified' natural forests rather forest plantations. While these measurement issues detract from the value of the data as the basis for an analysis, they need to be assessed against the considerable value of a data set that is both historical and global in its reach. This assessment suggests going ahead with an analysis, acknowledging all the while that it is exploratory in nature.

Table 1 presents the measures and the sources for the data used in the analyses that follow. If the forest transition hypothesis accurately describes the drivers of plantation expansion, then plantation expansion should occur in wealthier societies with declining rural populations. The political hypothesis would receive support if the presence or absence of a government policy to encourage forest plantations in a country makes a discernible difference in rates of forest plantation expansion. A human ecological explanation for forest plantation expansion would receive support if population density variables and related measures of forest per capita, the extent of cultivated land, and the extent of land in pasture figure centrally in explanations for the increasing extent of forest plantations.

The analysis includes nations from both the global north and south. A lack of data made it impossible to include two relatively small categories of nations in the analyses. Island nations with few people and limited resources frequently do not report data on land cover change to FAO, so they are not included in the analysis. Former Soviet states that became independent nations after 1990 are not included in the analysis because demographic data on these places for the 1980s could not be obtained. Eastern European nations that underwent a change in regime during the same period are included in the analysis.

The multivariate analyses of the data take two forms. Ordinary least squares (OLS) regression analyses of landscape change weight political jurisdictions equally. In other words in these unweighted analyses large continental countries like the United States count as much as small island nations like the Bahamas. Weighting the multivariate analyses by the size of a country's land area gives a somewhat different picture about the prevalence of particular patterns of landscape change. Large countries like Canada, China, India, Russia and the United States have an influence in these analyses commensurate with their size. I report both unweighted and weighted analyses in the following tables. Taken together, the two different multivariate techniques provide different but related perspectives on processes of forest plantation expansion around the globe.

Weighted analyses have an additional methodological advantage. With the data for each nation derived from government records, there will be variations in the amount of error from nation to nation. Some nations will have accurate cadastral records indicating the extent of forest plantations while others will not. Under these circumstances there might be problems of heteroscedasticity (unequal error variances) in the data (Berry and Feldman, 1985, p. 74). An inspection of the residuals plotted against values of the independent variables does not indicate the kind of skewed distributions in the residuals that would indicate heteroscedasticity. Nevertheless, the weighted least squares analytic approach provides a useful check on the OLS analyses because, like generalized least squares (GLS) estimation techniques, weighted least squares analyses produce unbiased estimators in the presence of heteroscedasticity (Berry and Feldman, 1985). The independent variables have condition indices of below 3 which indicate that the equations do not suffer from serious problems of multi-collinearity. As a result, the equations in Tables 3–5 all seem to be free of serious contaminating influences.

Table 1
Measures and sources for data

Extent of forest plantations, 2005	Extent of planted forests in a country in 2005 (in hectares). *Source*: Global Forest Resource Assessment, 2005 (FRA2005), FAO. Accessed at http://www.fao.org/forestry/site/fra2005/en/
Change in forest plantations, 1990–2005	Planted forest in 2005—Planted forest in 1990. *Source*: Global Forest Resource Assessment, 2005 (FRA2005); accessed at http://www.fao.org/forestry/site/fra2005/en/
Cultivated land, 1990	Cultivated land as a Percent of Land Area (crops and pasture), 1990. *Source*: Resource Stat, FAOSTAT; accessed at http://faostat.fao.org/site/377.
Forest plantation policy	Policy to Encourage the Creation of Forest Plantations. From Country Profiles at http://www.fao.org/forestry/site/fra2005/en/
Percent in pasture, 1990	Percent of Land Area in Pasture, 1990. *Source*. Resource Stat, FAOSTAT; accessed at http://faostat.fao.org/site/377.
Population density, 1990	Population, 1990/Area of Country. *Sources*: Penn World Tables at http://pwt.econ.upenn.edu/php_site/pwt62/pwt62_form.php. World Bank at http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS.
Forest per capita, 2000	Extent of Closed Forests, 2000/Population, 2000. *Source*: Global Forest Resource Assessment, 2005 (FRA2005), FAO. Accessed at http://www.fao.org/forestry/site/fra2005/en/.
Percent forested, 1990	Percent of Land Area in Forests, 1990. *Source*: Global Forest Resource Assessment, 2005 (FRA2005), FAO. Accessed at http://www.fao.org/forestry/site/fra2005/en/.
Percent change in rural population, 1980–1990	Rural Population, 1980—Rural Population, 1990. Divided by Rural Population, 1980. *Sources*: United Nations, Department of International Economic and Social Affairs, 1985 Estimates and Projections of Urban, Rural, and City Populations. United Nations, 1992. Human Development Report.
GNP per capita (logged), 1990	*Source*: Penn World Tables at http://pwt.econ.upenn.edu/php_site/pwt62/pwt62_form.php.

Table 2
Regional patterns of change in forest plantations

Region	Forest plantations as a percentage of all forests in a country	Extent of forest plantations, 2005 (thousands of hectares)	Change in extent of forest plantations, 1990–2005 (thousands of hectares)
Africa—Sub-Saharan	7.6	314	17
Asia—South and East	12.5	7605	3130
Asia–Central	10.8	243	.2
Europe—Northern	12.6	847	196
Mediterranean Basin (Southern Europe and North Africa)	26.7	509	135
North America	4.9	1449	584
Oceania	10.5	768	346
South America	6.8	1032	272

Source: Food and Agriculture Organization of the United Nations. FRA2005 Data base.

Results

Table 2 describes regional variations in forest plantation expansion over a 15-year period between 1990 and 2005. The expansion concentrated in South and East Asia; by 2005 countries in this region contained 62% of the world's recorded forest plantations. People planted trees in a wide range of other settings. Only Africa and Central Asia saw little change in the extent of forest plantations and, as noted above, the pattern in Africa may reflect problems with the data rather than an absence of tree planting in the region. The importance of forest plantations as a source of wood also varies regionally. While forest plantations only constitute 5% of all forests in the Americas, they represent more than 25% of all forests in the Mediterranean basin. The beneficiaries from tree farm expansion also vary regionally. In the Americas large landowners and corporations owned 67% of the forest plantation land in 2000, so most of the economic benefits from plantations went to already wealthy interests. In Asia private landowners running large industrial plantations only controlled 5% of all plantation land in 2000. States and villages controlled most plantation land. In addition people used large numbers of plantations for non-industrial purposes, as sources for fuelwood and as protection for water sources (Del Lungo et al., 2001). Given these different patterns of ownership and use, expansion in the extent of plantations should have quite different distributive consequences in South and East Asia than it does in the Americas.

The analyses reported in Tables 3–5 begin to identify the social forces behind plantation expansion. The cross-sectional multivariate analyses in Table 3 indicate in both the weighted and unweighted analyses that densely populated nations with little forest cover and considerable income have relatively extensive forest plantations in 2005. China exemplifies this pattern. The negative coefficients for cultivated land and for the population density–forest policy interaction term indicates that some large countries with low population densities, few policy directives, and little cultivated land still had extensive forest plantations. Brazil, Russia, and the United States would all fit this profile.

Tables 4 and 5 present analyses of changes in the extent of forest plantations between 1990 and 2005. In the overall unweighted analysis in column 1 of Table 4 only the control variable, percent of area in tree farms in 1990, associates significantly with changes in the extent of tree farms. In the weighted analysis in column 2 population density in 1990 and the population density–forest policy interaction term associate positively with plantation growth. Forest per capita in 1990 associates negatively with plantation growth. These findings most likely reflect the tremendous increase in the extent of forest plantations in densely populated places in South Asia (India) and East Asia (China and Vietnam) after 1990 (Mather, 2007).

Table 5 explores the regional patterns of plantation expansion. The findings for Africa in columns 1 and 2 suggest the importance of densely settled landscapes with large proportions of cultivated land, coupled with forest plantation promotion policies, in the expansion of forest plantations. In the findings for Asia–Europe in columns 5 and 6 rural to urban migration predicts forest plantation expansion (unweighted analysis), as forest transition theory would predict, but, like Africa, Asia–Europe also features a significant population density–policy interaction term (weighted analysis). The association between plantation growth and a low proportion of cultivated land in the same equation probably reflects conditions in Russia and the larger European nations. In the findings for the Americas and Oceania in columns 3 and 4 rural population stability, contrary to forest transition theory's predictions, predicts plantation growth (weighted analysis) as does extensive tracts of pasture land in 1990 (unweighted analysis).

Table 3
Variations in the extent of forest plantations across nations, 2005

	Unweighted analysis	Weighted analysis (by country size)
Population density, 1990	.022*** (.004)	.047*** (.006)
Population density, 1990* Forest Plantation Policy		−.019*** (.005)
Forests per capita, 1990	−.092*** (.028)	−.077** (.024)
Cultivated land as % of land area		−.074*** (.022)
GNP per capita, 1990	.005* (.002)	.002* (.001)
R^2 (adj.)	.270	.420
N of cases	114	114

Note: * = <.10, ** = <.01, *** = <.001. The numbers reported in the same row with the variables are unstandardized regression coefficients. Their standard errors are immediately underneath the coefficients. Regressions run on cross-sectional data for 1990 produces quite similar results.

Table 4
Determinants of growth in the extent of forest plantations, 1990–2005

	Unweighted analysis	Weighted analysis (by size of country)
% of land area in forest plantation, 1990	.736* (.381)	
% change in rural population, 1980–1990		.002* (.001)
Population density, 1990 * plantation forest policy		.043*** (.011)
Plantation forest policy	.039 (.026)	
Cultivated land as % of land area	.113 (.088)	
Forests per capita, 1990		−.148* (.089)
R^2 (adj.)	.055	.128
N of Cases	112	112

Note: * = <.10, ** = <.01, *** = <.001. The numbers reported in the same row with the variables are unstandardized regression coefficients. Their standard errors are immediately underneath the coefficients.

Table 5
Regional patterns in forest plantation expansion, 1990–2005

	Africa		Americas and Oceania		Europe and Asia	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
% Land in forest plantations, 1990	.019** (.006)		.031*** (.008)	4.947*** (.739)		
Population density 1990		.041* (.015)				
Population density 1990 * forest policy		.092* (.037)				.057* (022)
Rural population change, 80–90				.003** (.001)	−.016* (.008)	−.005 (.004)
Cultivated land as % of land 1990	.005*** (.001)		−.001 (.001)			−.257* (.122)
Forests per capita, 1990			−.190 (.142)			
% pasture, 1990		.003** (.001)				
R^2 (adj.)	.511	.267	.480	.685	.074	.129
N of Cases	38	38	27	27	47	47

Note: * = <.10, ** = <.01, *** = <.001. The numbers reported in the same row with the variables are unstandardized regression coefficients. Their standard errors are immediately underneath the coefficients.

Discussion

One of the more interesting findings in Tables 3 and 4 involves the changed sign in the coefficient for the population density × forest policy interaction term. In the analysis of the extent of forest plantations across nations in 2005, the coefficient is negative, indicating that many European and American polities with either low population densities or little policy direction regarding tree farms, nonetheless, have extensive tree farms. In Table 4 the sign switches. Recent increases in forest plantations occurred primarily in densely populated places with effective policies for promoting the expansion of forest plantations. China, India, and Vietnam, all of which promoted forest plantation expansion through a variety of political reforms enacted during the 1980s and 1990s, exemplify this pattern of forest plantation expansion (Mather, 2007). These regional contrasts point to the changing historical geography of plantation growth. While forest plantations first became fairly extensive in European and American countries that currently have relatively stable rural populations, most of the recent growth in plantations has occurred in the densely populated, extensively cultivated South and East Asian countries that have experienced substantial rural to urban migration during the past 30 years.

The results from the Asia–Europe analyses both confirm and challenge forest transition theory. As forest transition theory would suggest, rural to urban migration in this context appears (unweighted analysis, column 5, Table 5) to expedite the creation of tree farms because the emigrants abandon lands that then become the sites for forest plantations. Neither forest transition theory nor the political explanation anticipates the importance of high population densities, in combination with political initiatives, in promoting the expansion of tree farms in both Africa and Asia. Events in China, India, and Vietnam illustrate the dynamics of this interaction (Mather, 2007). In China a series of state led afforestation campaigns during the 1980s extended plantation forests, but the rate of expansion accelerated after the government introduced the 'grain for green' program in the aftermath of the Yangtze River floods in 1997 that gave small farmers financial incentives if they converted some of their fields into forest plantations. In India central government-led programs failed to end deforestation and degradation during the 1980s. The government then decentralized control over many forests, giving villagers a share of the proceeds from the sale of local forest products. Under these circumstances villagers begin to rehabilitate and restore forests (Poffenberger and McGean, 1996). In Vietnam devolution of some control over the proceeds from the land, coupled with an improved transportation network, led some villages and smallholders to abandon unproductive upland agriculture and rely on purchased foodstuffs from more agriculturally productive areas of the country. Villagers planted the abandoned uplands with commercially valuable species of trees (Mather, 2007). In all three countries the presence of millions of smallholders on the lands magnified the impact of the policy reforms, creating the observed interaction effect, on plantation expansion. This regional trajectory in land use change appears to characterize South and East Asia as well as parts of Southern and Eastern Africa.

The pattern of low population densities, no policy initiatives, and still substantial gains in forest plantations in the cross-sectional analyses would appear to describe rural regions in the Americas with extensive land uses (pastures), relatively stable rural populations, and large urban markets for wood. Because forest plantations in these places usually produce wood for industrial uses in local and global markets (Marchak, 1995), their managers want to produce wood on extensive tracts of land. This expansionist agenda sometimes places these managers on collision courses with the leaders of stable or expanding populations of rural residents, laying the bases for the political controversies surrounding forest plantations in Chile and Brazil. These large scale forest plantations and the associated pattern of change would appear to predominate in the Americas, Russia, and Oceania.

There are two regional trajectories and no single explanation for the current patterns of forest expansion. One trajectory, in Asia, Europe, and Africa, features dense populations of smallholders who plant trees, frequently with government assistance. The other, in the Americas, Russia, and Oceania, involves larger plantations, sometimes under corporate ownership. These patterns are probably best understood through a human ecological approach that incorporates and uses insights from both forest transition theory and state led theories of political change.

Conclusion

Questions about political dimensions appear particularly pressing in setting agendas for future research on forest plantation expansion. Given the increasing political salience of global warming and the ability of forests to sequester carbon, more state led efforts to increase the extent of forest plantations seem likely. While the contribution of carbon sequestering forest plantations to the overall solution of the global warming problem may be small relative to reductions in emissions of fossil fuels and declines in the continuing destruction of natural forests (Cossalter and Pye-Smith, 2003; CIFOR, 2007), forest plantation expansion is one of the few policy levers to counter global warming that would reinforce a trend already under way and therefore would be relatively easy to implement. Further research might address questions about the effects of different kinds of state interventions on forest cover, environmental services, and rural society. Mather (2007) has provided a

model for this type of inquiry in his recent comparative study of forest reforms in China, Vietnam, and India.

This research agenda presents both a challenge and an opportunity for social scientists and policymakers. Several of the regions with the most climactic potential for carbon sequestration (Sub-Saharan Africa, South, Southeast, and East Asia) also contain the worlds' largest concentrations of poor people. Under these circumstances payments for carbon sequestration from forest plantations could provide a valuable supplemental source of income for the rural poor. Efforts to realize this type of sustainable development must contend with two recurring patterns. First, the carbon sequestering plantations must not be carved out of existing rain forests, as has frequently occurred in the outer islands of Indonesia (Pirard and Cossalter, 2006). Otherwise, the emissions from deforestation nullify the gains from later sequestration. Second, states and corporations have managed most large forest plantations, in part because only they have the capital and secure land tenure necessary to create the plantations and in part because they have been reluctant to share profits with the poor who live around the plantations. For the rural poor of these regions to benefit from carbon sequestering plantations, they must secure tenure to these lands. Zimmerman (1951, p. 376, quoted in Lee and Field, 2005, p. 24) underlined the importance of this condition more than 50 years ago.

> "All perennial culture, but particularly the planting of trees, rests on the stability of social institutions. No one would be foolish enough to spend a decade or more . . .to build up an olive grove, which can bear fruit for a century unless he feels reasonably sure of a reward for himself and his descendants."

States and NGOs can help the rural poor reap benefits from carbon sequestering forest plantations by helping them secure tenure in land, negotiate payment for environmental services arrangements, and obtain the capital to plant the carbon absorbing trees (Boyd et al., 2007).

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