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THE RELATION BETWEEN POPULATION AND DEFORESTATION: METHODS FOR DRAWING CAUSAL INFERENCES FROM MACRO AND MICRO STUDIES

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I. Objectives

Does population growth have identifiable effects on the rate of deforestation at global and local levels? As occurs with analogous queries probing the relation between population pressure and other environmental outcomes, this is a question that has been intensely debated in the past but left without a satisfactory answer. And just as in other areas where population is invoked as a cause (or effect) of other environmental outcomes, this is not surprising since, as I show later, the conceptual and empirical difficulties to be surmounted are formidable. Somewhat more surprising, however, is the fact that we seem to have only a primitive idea about the nature and diversity of findings uncovered by past research. Indeed, a great deal of the discussion is dominated by grand-theorizing, overarching frameworks which are rarely if ever based on solid findings, and simulation exercises that impose and assume rather than verify relations between strategic factors. Not infrequently the controversy has been fueled by exegesis based on very selected evidence that intentionally or unintentionally discard and marginalize alternative results. Yet, a cursory examination of extant literature shows that there is an abundance of research findings that directly or indirectly relate to the main problem. Why, then, are we accomplices of a debate unable to marshall if not flawless at least solid evidence?

One must admit that, as a rule, the research findings alluded to above follow the trail of very diverse problems, are obtained with research designs that are hardly comparable at all, and are frequently based on the analyses of empirical cases or data sets that resist even the most ingenious attempts to find a reduction to common baselines. But perhaps a more important factor is the absence of systematic procedures to process these findings. I am not claiming that we lack adequate review studies, for of these we have plenty spanning the whole gamut of quality levels. Rather the point is that we have failed to develop and apply minimally rigorous techniques for the retrieval of estimates of the relation between population and deforestation or, for that matter, other relevant environmental outcomes.

What I set out to do in this paper is to describe and utilize two alternative procedures to derive inferences about the magnitude and direction of effects of population growth on deforestation. I do this by examining a relatively large sample of studies that were designed to answer the question stated at the outset. The first procedure involves statistical techniques that have evolved rapidly in the last ten years within the field of meta-analysis. The second technique requires the application of very simple principles of qualitative algebra to a set of case-studies where the relation(s) of interest are investigated. As will become clear in the discussion that follows, these two procedures are neither situated at the same level of abstraction nor are they in rife competition with each other. Even though one relies on premises about quantification of relations that the other purposely avoids and replaces, they can be seen as complementary. Since the empirical data required by these procedures are different, the inferences that we draw from each of them could be conflictive and may be even difficult to compare. Thus, while we should hail agreements and use them to reinforce conclusions, inconsistencies may be more a matter of incompatible data bases than the outcomes of relations that are unequally detected by the two procedures. I will argue, however, that meta-analysis is more limited not because of inherent shortcomings but due to the fact that its object of reduction, quantitative assessments of pertinent causal relations, cannot produce sufficient information about the range of causal conditions that lead to deforestation.

The organization of the paper is as follows: in Section II I describe the nature of the problem, roughly establish the boundaries of what we seek to understand, and highlight the most important analytic problems. In Section III I describe and apply meta-analyses to a handful of quantitative studies and in Section IV I explore the application of qualitative algebra to a sample of about 55 case-studies. Section V presents a brief summary and conclusions.

II. Consumption of forests and population pressure.

1. The extent of modern deforestation.

Clearing of forests is hardly an activity that emerged anew only recently. Forest clearing of large areas of Central Europe and the Mediterranean had been accomplished by 1300, after which it subsided for an interval of about 300 years (Hosier, 1988; Williams, 1990). Although the contribution of natural causes cannot be dismissed off-hand (Blaikie and Brookfield, 1987a), past episodes of deforestation appear to consistently emerge and peak after the onset of favorable economic conditions and wane during periods of economic stagnation. There is little if any evidence suggesting that population growth and removal of tree cover went in tandem, except perhaps to the extent that both were responsive to sharp swings in economic activity (Williams, 1989). In the developing world too the onset of deforestation precedes by some time the beginnings of the post-war population explosion. Thus, ecosystems in wretched conditions, such as the hills of Nepal, underwent important degradation long before modern population pressure appeared on the scene (Ives, 1987). In the Philippines the loss of forest land can be traced back to the early part of the century, when the country was under American colonialism (Bautista, 1990). And while in the Amazon region of Brazil the sharp increases in forest clearing did not occur until after 1975 (Barbier et al, 1990), in the South of Brazil (Rio Grande do Sul, Parana) and most of Central America, particularly El Salvador and Honduras, large territories covered with *Araucaria* and some rain forest had been devastated before 1970 (McNeill, 1988; Barrows, 1991). And yet, in both regions, Brazil and Central America, rapid population growth did not start in earnest until after 1950.

What is novel in the post-war cycle of deforestation is the scale and speed of the phenomenon. According to recent data, the global annual (percent) rate of deforestation measured in units of surface cleared between 1968 and 1978 is .51 (Allen and Barnes, 1985), a rate that is equivalent to a half-life of the forest cover of about 136 years. During the short interval between 1981 and 1985 the global annual rate of deforestation slightly increased to about .58 and the half-life of the forest decreased to 118 years (International Institute for Environment and Development and World Resources Institute, 1986). But the rate of deforestation from 1650 until 1850 can be roughly estimated to be at most one-fourth of that (Williams, 1990, Table 11.1). Furthermore, unlike most historical episodes of deforestation, current trends affect dense and massive tropical forests that comprise a substantial fraction of all existing forests. Unless arrested or slowed down, the sheer speed of the process and the magnitude of the area exposed to it rules out natural regeneration and charters a course of ecological degradation that may well be irreversible.

In addition to the size of the exposed area and the pace of clearing, current trends have an additional peculiar characteristic, namely that, by and large, the areas affected are located in the core of the developing world, in countries and regions experiencing the highest rates of population growth ever recorded. Undoubtedly it is this partially accidental feature--for clearing of dense forest can only proceed in areas where there are dense forests to be cleared--that provides access to an easy imagery sustaining claims about causal connections between population and deforestation. Causal inferences of this sort are further muddied by measurement complications that are conveniently swept aside. A brief summary of the most important among these complications is presented below.

2. "Bundling" the diversity of forests and deforestation.

There is a curious contrast between what our 'study of studies' will show and the nature of claims that are based on those studies, most of which identify population growth or high population density as the driving force of deforestation. As I will show below and as others have also shown before, the relations are far more complex than they appear on first scrutiny. Except in extreme cases population growth is only a remote cause of the problem, so removed in fact as to be somewhat useless not only for policy formulations but also for theory construction. And yet after examining the conclusions of nearly 70 studies on deforestation carried out in disparate regions during a period of approximately fifteen years, one is left with the strong impression that there is no question about the existence of a direct causal connection between deforestation and population growth or, more generally, population pressure. With slight differences of emphasis but sharper differences in perspectives and methodologies, in all these studies population growth is eventually invoked as a factor contributing to the rate of forest clearing. Some conclusions are blunt and leave scarcely any room for alternative explanations:

> "The slow and almost imperceptible increase in population during premodern times and its rapid rise from roughly 1600 onwards has led to a steady decrease of the world's forests as humankind has needed more land for growing food, timber for construction and shelter, and fuelwood to keep warm, cook food and smelt metals." (Williams, 1989)

or, less directly but not more subtly:

> "Given a population growth rate of 3.7 percent per annum, there is no doubt about the need to increase agricultural production. However, this should not be achieved by destroying the last remaining natural forests which are needed to carry out important ecological regulatory functions." (Kleinert, 1987)

Other authors are more cautious and suggest the presence of complexities that, upon further investigation, could conceivably overshadow the role of population without necessarily displacing it from its prominent position. Here, the importance of population is toned down, inserted in a more conservative causal discourse that reflects some reticence to dispose of the nagging issue altogether, even if that is precisely what the evidence calls for:

> "Although the rapid increase in population growth in the region [Central America] is a matter for serious concern, population growth per se cannot adequately explain the destructive land-use patterns that have emerged in the south." (Stonich, 1989).

Occasionally population will appear as an afterthought, another item in a lengthy and heterogeneous 'shopping list' of causes, perhaps more as a concession to an entrenched tradition than as a reflection of relations and mechanisms disentangled in empirical research:

> "To summarize, it can be said that deforestation is caused by the combination of a number of factors. It is difficult to identify a single cause and account for its share. The combined influence of economic pressure, population pressure and Government policy have together precipitated the present alarming situation." (Chattopadhyay, 1985)

or, when the list is longer,

> "In other words, deforestation is a consequence of low per capita income, non-availability of fossil fuels, high population density, and poverty; hence, it is intricately linked to socio-economic process."(Bowonder, 1985)

a. *Diversity in deforestation.*

Clearing of semi-arid or moist tropical forest, rain forest, humid temperate forest, and savannah woodland is conceived as an essentially negative outcome because, in addition to seriously undermining the aggregate value of amenities it leads to loss of bio-diversity, laterization, erosion, soil degradation, siltation of streams and reservoirs, and exacerbation of conditions that could produce global warming. The discounted value of the economic benefits derived from forest clearing, so go some persuasive arguments, simply does not stand up to the societal costs that will burden current and future generations. Others argue that under some conditions, deforestation is a perfectly rational activity at least insofar as the calculus of cost and benefits is concerned (Hosier, 1988). This raises a first complication related to the homogeneity of the outcome: can one lump in one single bundle all clearing and tree-cutting activity and manipulate one single outcome-measure? Or, alternatively, should one make allowances for heterogeneities that reflect at least partially short- and long-term environmental outcomes? Plainly, the thinning-out of a tropical forest as a result of heavy-handed, high-tech logging activities cannot lead to the same environmental spill-overs as would, for example, the clearing of an equivalent area of dry forest for fuelwood harvesting. It is not just the type of human action that matters--although clearly this contributes to the differences--but the quality of the stock of tree cover being sacrificed and the residual ecological resiliency or fragility. The choice is far from obvious, for while the strategy of 'bundling indicators' facilitates measurement but introduces confusion, the other strategy complicates the empirical investigations (and may even make them impossible when the information is simply unavailable) but may preserve significant distinctions.

Though related to the first, the second complication is quite different. It is that forest clearing involves a wide range of human activities with very different consequences and, one would think, very different determinants: it stretches from tree-cutting for woodfuel and charcoal production to indiscriminate clearing to extraction of selected and highly valued roundwood. Caught in between is the clearing that occurs as a result of swidden agriculture, as shifting cultivators move from one plot to the next, in an endless but losing battle to prevent precipitous falls in yields or, alternatively, the establishment of extensive grazing fields to raise cattle in ranching operations geared to export markets.

A third complication is somewhat more pedestrian in inspiration but could, in all likelihood, produce a host of unanticipated and nasty consequences. If one decided that the magnitude of deforestation is to be measured by a single indicator that bundles all tree losses or area cleared, with no distinctions made about the nature of forest cover or the human actions involved, how are we to construct the indicator? Absolute area cleared or volume harvested is not a good choice since decrements will be roughly in proportion to time elapsed and areas (or volume) exposed. Since current 'stumpage' stocks are largely concentrated in countries with high rates of population growth, a graph displaying absolute decrements per unit of time against population will inevitably tend to show a positive relation. But this involves no causation, not even an informative relation. Obviously, a similar diagnostic applies when the units of analysis are villages and their contiguous territories or districts and provinces. A far better measure is the monthly or annual rate of clearing or the log of the ratio of forested area at time t+n to forested area at time t. This, of course, presupposes that we have good means of assessing the magnitude of the area cleared and that we have the means to set up equivalence classes of lost forest as a function of potential natural regeneration. With a few exceptions, most literature on the subject proceeds as if this latter complication were trivially solved. We found no good analysis of the potential pitfalls or of the degree of correspondence between observed area cleared and secondary environmental damage.

Finally, the nature of the product being cleared in combination with the methods used to do it surely results in different probabilities of and waiting times for regeneration of the tree cover. When this heterogeneity is considerable, a single indicator of deforestation is likely to hide so much diversity regarding potential environmental outcomes and prospective carrying capacity as to be totally meaningless as a proxy for the ultimate environmental influence that deforestation will exert.

b. *Dimensions of population growth.*

Although elementary, the distinction between population growth and population density is frequently overlooked. Somehow the proposition that 'high rural population density leads to deforestation' is used interchangeably with the proposition 'rapid rural population growth leads to deforestation' and no care is taken to establish their inherently different implications. Whereas over time high population density inevitably results from population growth within fixed geographic boundaries, there is no necessary correlation between one and the other in a short interval of time and over diverse geographic locations. The mechanisms linking deforestation to population pressure that results from rapid growth but not high density, on the one hand, and to pressure derived from high density but not rapid growth, on the other, are bound to be different. The differences may exert non-trivial influences on research results particularly when, instead of following the more comfortable strategy of using the 'single-bundle' approach, one chooses to distinguish different types of deforestation.

A related but distinct conceptual shortcoming is immediately erected as soon as population is conceived simply as the absolute number of people or its relative growth. There are other dimensions of the structure of a population that may have non-trivial effects on the uses and misuses of forests such as the age distribution, settlement patterns, and the distribution of individuals by types of households or familial arrangements. Just as population density and population growth need to be kept separately, so should the various dimensions or the distributional aspects of population.

As with other environmental outcomes, the study of the relation between population and deforestation is usually done on well defined legal and territorial entities, usually countries or, more rarely, villages and districts. While in all these cases the precise locus of deforestation is well defined, the locus of population growth or density may not be altogether obvious. Indeed, it could depend on the type of activity leading to deforestation. Thus, when deforestation results from land clearing to accommodate an over-supply of agricultural labor force, the approximate unit of reference or measurement is the country or village or district that generates the excess population growth choking labor markets. But, when deforestation occurs as a result of intensive logging, the unit of reference is no longer obvious and largely depends on the exact mechanism linking demand for timber, social distribution of returns from exports, and/or population pressure, if any, that sustains the demand for the product. It also depends on how population pressure is alleviated by allocating the returns from logging.

This brings up a final issue. Unequal regional population distribution--which is, in part at least, a reflection of differential rates of natural increase--may lead to deceivingly simple imageries. Thus, for example, government sponsored resettlement policies and programs--either directly enforced or indirectly stimulated by subsidies and incentives--reshuffle the spatial and sectorial distribution of labor and, in the process, may alter the demand for land occupied by pristine forests. While the argument that population growth is the ultimate culprit is indeed suggestive, it is also somewhat uninformative and misleading for the relations involve many layers that need to be peeled away before the causal mechanism is exposed: unequal population distribution, unequal regional rates of labor demand formation, and resettlement policies are important pieces in the puzzle and need to be examined before simple statements of relations can begin to be considered seriously.

3. The nature of the relation.

Conventionally, population growth and selected economic outcomes (income per capita, for example) have been linked together through generalized 'production functions' that translate factor densities into output. The translation is subject to some constraints, usually associated with technology and elasticities of response of output to factor inputs. In regimes with a positive rate of population increase, the long run behavior of the system largely depends on whether there are *a priori* defined mechanisms to escape excessive population growth. This occurs if returns to scale are more than marginal and figure prominently to arrest slumping per capita output or, alternatively (but more commonly, complementarily), when technological improvements that trigger an upward displacement of output at fixed values of input factors are themselves responsive to population pressure. When no such mechanisms are provided, the entire system is doomed at least in the long run. This, in a nutshell, is what makes the difference between a 'Malthusian' view and a 'Simonian/Boserupian' approach.

Arguably, a similar representation could be used to describe the process of deforestation. The 'product' is a measure of the extent of forest cleared in an interval of time while the factor inputs include population (or labor force), arable land and technology with associated elasticities:

$$D(t) = g_{(\alpha,\beta,\delta)}(P,L,T) \qquad (1)$$

where g is a suitable functional form, P is population, L arable land and T is technology and α, β, δ are elasticities. Manipulations of (1) lead to expressions for the rate of deforestation as a function, among others, of the rate of population growth (or population density). As I will show later, this is the type of reasoning that leads to linear models tailored to the estimation of elasticities that are sometimes construed as measures of 'causal effects.' Most of the quantitative studies that have been carried out in the past ten years or so rely on formulation analogous to (1). This approach, however, has two main problems.

a. *Heterogeneity of the outcome.*

While (1) may be a sensible representation for some types of deforestation, it may be inaccurate for others. Deforestation that occurs largely as shifting cultivators nibble away progressively large patches at the edges of forests, could in principle be represented by expressions analogous to (1). However, deforestation that occurs as an outcome of heightened demand for cattle pastures or for timber, is likely to fall outside the boundaries of (1). This is a very important and vexing issue that is regularly obscured in almost all quantitative research on the subject though, admittedly, much less so in case studies. The point is not just that the input factors may be different or that the elasticities are variable across outcomes (types of deforestation) but that the relation between them and at least one of these factors, namely population, is far from being reducible to a common expression. It is simply nonsense to argue that population pressure acts homogeneously since it may indeed be the case that it plays no role at all in at least some of the outcomes or, more radically, it may exert influences moving in opposite directions. If, as is very commonly done, one neglects this heterogeneity, estimation of effects will lead to biased and uninterpretable estimated effects.

If most deforestation occurred as a function of one mode of action alone, these caveats would be purely academic. But extant data confirm the conjecture that forest clearing involves substantially heterogenous activity and that the degree of heterogeneity varies across regions. Although the data bases are not ideal, they do show that the proportion of forest area cleared attributable to woodfuel demands, timber extraction, and cultivation changes over time and across regions (Williams, 1989; 1990; Allen and Barnes, 1985; Biswas, 1986; Bowonder, 1985)

b. *Contingencies and mediating factors.*

But the single most important charge that one can level against the representation in (1) is that it operates in an institutional vacuum. This means that it neglects (a) that the effects of population on deforestation are mediated by a chain of social processes and (b) that their magnitude and their direction is contingent on the presence (absence) of social institutions. Two examples show the importance of mediating factors and contingencies.

The first example is a simple one. It refers to the extent of deforestation produced by clearing for fuelwood. Apparently the connection between area deforested (A) and population (P) is quite straightforward: per capita needs of energy for cooking and heating (e) when multiplied by total population results in the total amount of energy needed. Parameters translating energy requirement into volume of wood (λ_1) and volume of wood into area cleared (λ_2) complete the equation relating population and area of the forest cleared:

$$A= P\ (e\ \lambda_1\ \lambda_2) \qquad (2)$$

A straightforward algebraic consequence of the expression is that an increase of x percent in the population will imply an increase of x percent in the area cleared. With some cosmetic changes this type of argument is consistently made in many studies, particularly those that focus on Africa and some parts of Asia: the connection is transparent and immediate and there can be no doubt about what the role of population pressure is. Furthermore, the evidence available does seem to confirm it: the postulated relation is such that if population grows exponentially, so will the area of forest cleared. Figure 1 taken from the excellent review by Williams (1990) does indeed indicate that consumption of forests to satisfy woodfuel demands follows a roughly exponential trajectory. More than 90 percent of the total wood extraction in low-income, rapidly growing countries and half of the wood extracted from the forests of the world is for woodfuel usage (Bowonder, 1985; Williams, 1989). It is not surprising then that total correlations between extent of deforestation and population growth are more than trivial.

{Figure 1 about here}

But expression (2) is artificially simple to capture the complexities of any empirical case and, in all likelihood, will not lead to correct results if the time horizon is expanded beyond a few years. There is ample evidence that relentless use of the forest to satisfy woodfuel needs does indeed take place under certain conditions, e.g., those that allow the unregulated use of common property resources when alternative fuels are prohibitively priced. The outcome could be different if property rights were established so that benefits and costs were spread across all economic agents involved in extraction, exchange and consumption. Under such conditions, price increases would inevitably derail the process and the connection between population and area deforested could be lost or attenuated. But lack of efficacious mechanisms to internalize externalities is only partly responsible for the inaccuracy of the representation. Another element that favors unrestricted forest clearing is excess supply of labor force. As recognized by Whitney in an analysis of Sudan:

> "In subsistency fuel gathering, exemplified by much of rural Sudan, location utility is expressed not in monetary terms but in terms of the effort and time expended to collect and transport the wood. If the opportunity cost is zero, or the demand for wood is inelastic, a much greater effort will be expended on fuel collection, with resultant deforestation, than in a situation where the opportunity costs of labor are rising or where the demand for fuel is elastic. In the former situation, fuel gatherers will continue to exploit one area until the perceived marginal effort of producing the next unit of fuel exceeds the effort of moving to a more distant area where wood is more plentiful." (Whitney, 1987).

Low prices of fuel for the urban population, the source of a large part of the demand for woodfuel in many countries, are indeed desirable to central governments. Import-substitution relying on the more expensive fossil fuels or regulations that decelerate the process of clearing but would increase pressure on prices are not politically viable. Thus, the relation represented by expression (2) rests not only on conditions dominated by 'Hardin-type' of transfers (McNicoll, 1990) but requires also an acquiescent central authority unwilling to shake up their foundation and, finally, a plentiful supply of labor. The effects of population growth are then a function of, or are contingent upon, the joint occurrence of a peculiar set of property rights, an urban-biased central authority, and a production structure with a low rate of labor absorption. Conceivably, changes in some or all these three conditions could lead to a partial or complete dissociation between population growth and deforestation. If these conditions approximate reality well, we would observe that a function defined in a high dimensional plane relating deforestation, population growth, property rights, central authority and production system, would be highly non-linear, and that the partial derivatives of deforestation with respect to population growth would be themselves highly non-linear. This more nuanced representation completely negates the practical value of the commonly used 'average' effect of population growth on deforestation.

The second example illustrates the operation of mediating factors and contingencies. At least during the initial stages of a demographic transition, population growth leads to increases in the rate of increase of families or households, not just to increases in the absolute size of the population or population density. In the absence of other changes, this will accelerate land fragmentation and exacerbate the inequality of land distribution. This, in turn, could affect the returns to labor, the number of hours worked, and the kind and quantity of activities devoted to preservation of land quality and conservation of complementary natural resources. Intensification and extensification are both plausible reactions and, in particular, indiscriminate land clearing could end up being the dominant response to the inevitable onset of declining yields. The future turn of events will depend on social and political conditions supporting (undermining) economic transfers. This is hinted at in an interesting paper by Thiesenhusen (1991) who suggests that some societies under high population pressure and undergoing rapid fragmentation of property may be highly resilient and could delay or prevent altogether the release of excess labor force into marginal areas. The feat is achieved through the use of networks of social exchanges and systems of obligations. Within limits to be empirically explored, a system of social and economic exchanges and obligations could deflect, in significant ways, the pressure on resources generated by sheer increases in the labor force. Within those limits, the linkage between the growth in the labor force and deforestation or other environmental outcomes will be only a weak one.

This example illustrates two points. First, population growth operates through land inequality and both factors are part of a rather lengthy causal chain: the more remote the connection (the higher the number of intermediate stages), the less relevant will population growth be and the higher the likelihood that its effects will be twisted, bent and even dissipated by a sequel of contingencies punctuating the chain. This does not mean that population growth does not have any effects: it only implies that its effects are felt insofar as they are efficiently transmitted by mediating factors. Second, the effects of population growth can be attenuated and delayed within social and political contexts that favor the reallocation of wealth and cushion the fall in per capita yields. These social and political conditions are thus contingencies that alter the responses to changes in population growth.

Our review of the literature reveals that the most important mediations and contingencies involve five factors: the fragility of the ecosystem, the stock of active (or passive) production technology, management techniques and knowledge, social and political institutions, and cultural frameworks. Moving the debate beyond polarized views requires us not to abandon altogether the idea that population growth may have an effect on deforestation but to carefully identify those conditions that determine 'when' and 'where' the effect will be weak or strong. As in the case of another environmental outcome such as land degradation examined by Blaikie and Brookfield (1987b), deforestation "[...] can occur under rising population pressure, under declining population pressure and without population pressure...Population is certainly one factor in the situation, and the present rapid growth of rural populations in many parts of the world makes it, in association with other causes, a critical factor. But 'in association with other causes' is the essential part of that statement, for the other causes themselves can be sufficient...". The analyses that we present later illustrate well the idea of a complex web of causality and justify the cautious position adopted by Blaikie and Brookfield. Indeed, we uncover that at least four of the five factors identified above appear repeatedly in a large sample of cases of deforestation.

In an effort to establish a solid if provisional base for theorizing, we now turn to the analysis of extant studies. We will attempt to make inferences about the strength, direction and significance of the effects of population growth on deforestation and about the type of mediating mechanisms and contingencies (the 'other causes') that modify those effects. We will show that the effects of population growth if not trivial are somewhat weak and, more important, cannot be easily interpreted in the absence of a discourse including mediations and contingencies. We begin with a meta-analysis of quantitative studies.

III. Meta-Analysis of the effects of population growth on deforestation.

There are three types of studies to verify, disprove or inform the relations that we are analyzing. The first are simulation models. Through complicated relations they enable us to calculate an estimated ultimate effect of either rate of population growth or density on any environmental outcome that we care to specify. There are two types of simulation models: those that produce negative results and those that produce positive results. The main problem with these models is that the relations that drive the simulation models are for the most part assumed and not verified. And since there are so many of them, it is difficult to know to what extent the results are consistent with the actual course of events in a geographic area during a well defined period of time. The fact that slight modifications to the representation of the main relations lead to diametrically opposite results should alert us to the perils of this type of models. Although they are not well suited for the production of sound inferences, simulation models are important tools to understand the implication of causal representations and to guide the collection of relevant information.

The second type of studies are those that use aggregate relations and employ a variable-oriented approach (Ragin, 1987). Here the aim is to examine and quantify the relation between variables, some of which are called independent whereas others are dependent. Meta-analysis is tailored to derive statistically sound inferences about the magnitude and significance of the effects of independent variables on dependent variables from a collection of these studies.

The third type involves case studies that deal with a complete causal configuration. It has been conjectured that since the case-study approach is holistic one can learn more about mediating mechanisms and contingencies, assess better the degree of causal remoteness between two factors, and identify more efficiently the various causal configurations that lead to some outcomes of interest. The problem is that there may be many case studies but no single standardized procedure to synthesize the results. In Section IV we apply a procedure based on qualitative algebra to draw causal inferences from samples of case-studies.

1. **A brief introduction to meta-analysis.**

The aim of meta-analysis is to provide "a single set of numbers that describe and summarize the results of independent pieces of research" (Mullen, 1989). It consists of a series of statistical techniques that are designed to convert disparate statistics used in primary level studies to a common metric, to use the transformed statistics to assess the magnitude and direction of effects and, finally, to test hypotheses about the relation between results at the primary level and selected characteristics of the studies. The unit of analysis in meta-analysis is a primary level hypothesis test rather than a 'subject' (individual, community, country). The hypotheses test might be of the form 'X exerts a positive effect on Y' and primary level studies designed to verify it will generally yield statistics representing the magnitude and statistical significance of the effects of X on Y. Procedures in meta-analysis are tailored to generate inferences to verify the hypothesis and the statistical tools are constructed to gauge typical responses (of Y to changes in X), their degree of dispersion, and the association of variability of responses with characteristics of the primary level studies.

In an ideal primary level study of the relation between population growth and rate of deforestation one would seek to estimate the magnitude of the change in deforestation associated with a change in the rate of increase of the population. For simplicity, assume that we have two groups of populations, one with 'high' rates of population growth and the other with 'low' rates of population growth. A reasonable measure of the effect of the rate of increase would be D, or the difference in the rate of deforestation between the two groups divided by the standard deviation of rates of deforestation. With a simple formula we can transform this statistic into a coefficient of correlation between the two variables, r, a unit normal variate or a Z_{Fisher} measure. Similarly, if the study yields t statistics, simple expressions can be applied to covert them into the common metric Z_{Fisher}, D or r. If one were to identify K studies each producing a statistic transformable into the Z_{Fisher}, D or r metric, we could calculate a summary or combined statistic measuring the magnitude of the effect across all studies as well as a normal variate statistic to test the null hypothesis of no effects. The combined value is then back-transformed into a more interpretable average value, D^* or, alternatively, into an average level of significance, p^*. The latter is the likelihood associated with D^* that the combined results of the K studies would have been obtained under the null hypotheses (of no effects of population growth on the rate of deforestation).

Meta-analysis can be pushed further to answer the following question: is the inter-study variability in the transformed statistics statistically significant? And if so what are the factors that could explain the variability? This is an extremely useful feature of meta-analysis. In fact, our previous discussion suggests that deforestation is a heterogeneous outcome responding to sharply different activities each of which may be influenced by disparate determinants. Furthermore, population pressure may exert very different effects on these activities. If the K studies do not differentiate type of deforestation but, instead, use the 'bundle' indicator described in Section II, it is likely that the estimated (transformed) effects of the rate of population growth will differ significantly from each other. Suppose furthermore that population pressure is only relevant for deforestation that involves 'extensification' due to clearing by shifting cultivators. It should then be verified that the (transformed) effects differ significantly across studies and, furthermore, that they are systematically associated with the fraction of deforestation attributable to land clearing for swidden agriculture characteristic in each study.

2. **Meta-Analysis of quantitative studies.**

A bibliographic search extending back to 1975 produced 8 eligible studies. Of these we kept only 4 that satisfied the following conditions: (i) they explicitly formulate a model relating deforestation to population pressure with clearly defined variables; (ii) estimate the magnitude and direction of the effects (possibly in the presence of other variables); (iii) provide information on estimated effects, levels of significance, t or p statistics and sample size information.

The search was based on two different principles. We first located several studies where the evidence for/against deforestation was reviewed. We then used an ascendancy approach to trace references to published papers that summarized quantitative findings. We complemented this by tracing papers that cited the earlier studies. Second, we identified a set of major journals that devoted published space to related topics and scanned their indices for the period after 1975.

Three remarks about the nature of these studies are necessary. First, some of the studies grouped observations according to geographic location and used different definitions of population pressure. One study estimated the effects of population density as well as of population growth. In yet another, estimates were obtained separately for Latin America, on the one hand, and Africa and Asia on the other. Finally, rural and urban population growth were treated as alternative indicators of population pressure. Although by doing so we weaken the validity of the independence assumption on which the meta-statistical tests rest, we treated separately the various set of estimates, as if they were distinct primary hypothesis tests. This implies that we have not 4 but 8 different (but possibly dependent) tests of hypotheses. Had we had access to the original data we could have produced statistics that would have preserved independence while simultaneously accounting for the diversity of indicators for the independent variable. But this was not possible and it is rarely possible in other examples of meta-analysis.

The second remark is that all studies use a different model specification, e.g., the set of control variables are not identical. We initially ignore these discrepancies but we then make full use of them to seek explanations for patterns found in the studies' findings.

Finally, while it is impossible for us to standardize the procedures of estimation used in each study, we can fully investigate their potential effects on hypotheses verification. For example, if one were concerned with the effects of outliers on the results, we could gauge their effects provided that we had studies that dealt with outliers differently. If in all studies the existence and treatment of outliers is simply not mentioned, it is impossible to discern if and to what extent the inclusion of outliers is relevant for inferences.

{Table 1 about here}

The main results are displayed in Tables 1 and 2. In Table 1 we summarize the information retrieved from the studies, their characteristics relative to some strategic factors, the transformed statistics, and some basic statistics for comparison. Note that with one exception, in all studies population pressure increases deforestation (the relation is positive) and that in three of them these effects are statistically significant. The statistics for the weighted (by sample sizes) combination of studies show that the effects are statistically significant (combined Z equal to 5.20 with p equal to .00012). This indicates that the results in Table 1 are unlikely to obtain if the null hypothesis (of no relation between deforestation and population pressure) were true. A good metric for the size of the effects is D: it is equivalent to the difference in the rates of deforestation (expressed in units of standard deviation) that would be observed if we divided our sample into a group with high population pressure and one with low population pressure. Thus, a value of D=. 89 (see Table 1) indicates that the difference in the rates of deforestation between low and high population pressure environments is equivalent to about .89 of a standard deviation, a relatively modest impact indeed.

It can be argued that the validity of these results is highly dependent on the degree of selectivity associated with the studies that were retrieved and that different results would obtain had we selected <u>all</u> the quantitative studies that were carried out during the period of time considered, not just those published. Indeed, it could occur that the studies that were published in more visible journals (or published at all) are precisely drawn from among those that erroneously reject the null hypothesis of no effect. This is the so-called 'file drawer problem' (Rosenthal, 1979). Although there is no solution for it, we can gauge its extent by calculating the 'fail-safe number' or the minimum number of non-selected studies (unpublished or appearing in marginal publications with a low probability of being traced) showing null results that would be needed to overturn the alternative hypothesis of existence of effects. For our study this number is 75 which, though not comfortably large, is large enough to provide some confidence in the results of the meta-analysis. Another way to explore the possibility of publication bias is to examine the existence of general patterns of association. Figure 2 displays a plot of the estimated size-effects (D) associated with each study and the sample sizes (N). One would expect that this figure resembled an inverted funnel with its center located approximately over the value of D that represents the true effect (Mullen, 1989). The plot in the figure does not replicate an inverted funnel shape and instead does suggest the existence of bias against studies with D<0, precisely the type of expectation harbored by a selectivity argument.

Although mixed, our results point toward the conclusion that the sample of cases contains a bias against the null hypothesis of no relation between deforestation and population pressure.

{Figure 2 about here}

Are there any patterns in the estimated levels of significance and size of effects? Can one say that some primary hypotheses tests are more likely than others to show up significant and sizeable effects? The first conjecture is that studies where the control variables include mediating institutions or factors that are likely to create spurious relations or intermediate mechanisms or contingencies, should reveal effects of population growth that are closer to 0. Thus, for example, in studies where there are controls for demand for woodfuel and land clearing due to shifting cultivation (or for suitable proxies), the residual variation in deforestation attributable to population growth after controlling for these two mediating factors should shrink significantly. The second conjecture is that when population growth is used as an indicator of population pressure the results should be different from those obtained when using population density. To explore these conjectures, we proceed in two different stages. In the first stage we simply calculate statistics that reveal whether or not the variability of results in the various studies is significantly high. This is shown in the first panel of Table 2. The chi-squares values are uniformly high and significant indicating the presence of non-trivial heterogeneity in the results. In the second stage we break down the analysis by strata. We use two different stratification principles to define the strata. The first refers to the inclusion in the models of controls for potential confounders. The strata are defined as follows: tests with appropriate controls (strata I) and tests without appropriate controls (strata II). The second stratification principle is the type of indicator for population pressure. The strata are as follows: tests using population density (strata III) and tests using population growth (strata IV). Although it would have been desirable to discriminate also among studies according to their treatment of outliers, this was not possible since in none of them was there an explicit treatment of the problem.

{Table 2 about here}

The results displayed in the second panel of Table 2 show that the expectations are supported by the information. In fact, although the Z statistic is lower in strata II than in strata I, the D statistic is, as expected, much higher. In both cases the Z statistic is significant at less than .001. The results obtained with strata III and IV also behave in accordance with expectations: in strata III the Z value is low and insignificant, whereas in strata IV the Z value is statistically significant. Similarly, the statistic D is about 30 percent higher in strata IV than in strata III.

The relation between statistics from primary hypothesis tests and presence/absence of appropriate controls and utilization of growth or density is examined further in the third panel of Table 2. There we have calculated the parameters of a linear structure imposed to describe the relation between D values and membership in the strata. As can be seen, the p-values are relatively high, suggesting that the likelihood that the outcomes of the 8 studies varied linearly as a function of the predictors (either presence/absence of suitable control or use of population growth or population density) is quite low.

To summarize, these simple meta-analytic tests show that the primary studies were performed on samples where population pressure exerts a gross positive effect on deforestation. However, this finding should be heavily qualified. First, the magnitude of the effects of population pressure is at best only modest. Second, the meta-analysis indicates that, though no linear structure can be invoked, the results change according to the nature of the indicator used for the independent variable and depending on the presence (absence) of suitable controls. This is important since, as we show later, case studies do confirm that population growth may be related to deforestation but only if some other conditions prevail. In this sense the results of the meta-analysis are quite consistent with the results to be presented later. Third, although the tests performed were not completely decisive on this point, there is evidence suggesting that the sample of primary hypotheses tests is biased against the null hypothesis.

We complete this section with an important caveat. As we were not able to test the importance of the role played by outliers in primary studies, we are left only with the possibility of tentatively assessing its potential impact. Other studies (Bilsborrow, 1992) have suggested that the relation of population and deforestation is unduly influenced by outliers. In particular, it has been claimed that the estimated partial effects of population growth is much lower when conspicuous outliers are removed. If this is uniformly so, two complementary conclusions follow. The first is that the principal result of our meta-analysis should stand **even when the role of outliers is accounted for**. That is, the magnitude of the effects of population pressure on deforestation is by all accounts small, and if anything, our analysis should provide a conservative, upper-bound estimate of its effects.

In the absence of heavy measurement errors, the occurrence of outliers can only be explained by misspecification of the main model. Thus if, as we suspect, outliers are indeed present in at least some of the 8 studies, it follows that a focused meta-analysis will reveal that part of the strong heterogeneity we found in the primary results is fully attributable to exclusion (inclusion) of outliers. This reasoning leads to our second conclusion, namely, that a hypothetical meta-analysis carried out with full information about outliers would simply make more precise the nature of the factors to be included in the model but will not be inconsistent with our finding regarding the presence of underlying contingencies or mediations.

IV. A qualitative approach.

A quantitative approach that seeks to estimate the magnitude of association between variables is limited by the fact that it cannot shed much light on complex causal connections where the outcomes are functions of multiple joint contingencies and mediations. Recall that we argued that simple linear functional representations are unlikely to suffice as representational devices of causal mechanisms. This is not just an issue that can be solved with better measurement, by adding more variables to an equation, or by invoking non-linear functions, no matter how complex the equation ends up being. Rather it is a problem rooted in the type of causal complexity that the approach can (or cannot) handle. Derived from families of production functions, the postulated equations are not compelling enough as devices to capture the environment of institutions that play decisive roles in the ultimate effects of population on deforestation (and vice versa).

An alternative approach is to examine the findings of case studies designed to account more fully for the characteristics of actors, or institutions that accompany the occurrence/non-occurrence of an event of interest. The result of several case studies can then be examined to retrieve patterns or sequences of conditions that seem to occur (or be absent) together with an outcome. A tool of analysis is Boolean algebra which has been proposed and systematized by Ragin (Ragin, 1987). In what follows we apply this methodology to between 50 and 55 case-studies to disentangle the causal mechanisms that are likely to be involved in processes of deforestation. As we will show later, our findings indicate that although population growth is clearly in the background, it is far from being a very powerful force at all. Instead, the case-studies reveal the recurrent presence of a handful of mediations and contingencies that sometimes in isolation of population growth and sometimes jointly with it precipitate instances of accelerated deforestation. The meta-analysis revealed that we have only weak grounds to attribute much causal relevance to population pressure and that there are other factors that could be playing a significant role. What quantitative studies did not reveal (but rather obscured) is the type of mediations and contingencies with the potential to swamp the effects of population growth.

1. A brief introduction to qualitative algebra.

Most of the empirical research on the relation between population pressure and deforestation is based on case studies: self-contained descriptions of technology and culture and of the social, political, economic and demographic characteristics that are associated with activities leading to clearing of forests. The studies differ in terms of the units of analysis, the geographic and temporal location, the historical detail and the depth of description and use of quantitative materials. They have in common, however, a holistic approach to identify the configuration of causes that trigger the outcome of interest. Another shared feature is that, by and large, they rely heavily on measurement strategies on discrete rather than continuous spaces so that constructs are measured as presence/absence of some characteristics or outcomes.

Assume that we are able to identify 15 case studies of deforestation. Deforestation, D, is operationalized as a dichotomy: it can be rapid, in which case D=1, or slow or nonexistent, in which case D=0. Case studies have uncovered or sought to identify the role of the following three dichotomic factors:

i) land distribution (L): can be unequal with a plentiful supply of landless peasants, in which case L=1. Alternatively, land might be more or less equally distributed though pockets of 'hacienda' or 'fundo' or 'latifundio' property and of landless peasant may persist. In this case L=0.

ii) titling policies (T): can be well defined and based on long-term agreements more or less independently of year-to-year yields, sustained on an ample credit supply. In this case T= 0. Or, alternatively, it can be ill-defined, based on current exploitation and yields and eroded by a shortage of credit and imperfect credit and capital markets. In this case T=1.

iii) population growth (R): can be high, with high rates of new household formation and high rates of entrance into the labor force (R=1) or it can be mild with a slow rate of family formation and of entrance into the labor force (R=0).

A study of fifteen hypothetical case-studies, each associated with one of the 8, (2^3), possible causal configurations, reveals the following patterns:

L	T	R	D	Frequency (No of Studies)
1	0	1	1	3
0	1	0	1	2
1	1	0	1	1
1	1	1	1	2
1	0	0	0	1
0	0	1	0	1
0	1	1	0	3
0	0	0	0	2

According to the first row, in three studies deforestation occurred in the presence of land inequality, well defined titling and high population growth; according to the second row, in two case-studies deforestation occurred in the absence of land inequality and population growth but when titling was ill-defined, and so on.

A few remarks about the hypothetical 'data base' are in order. First, note that, although the case-studies illustrate all possible combinations of conditions, this is not necessary and, moreover, it will seldom occur. By and large, the diversity of empirical realizations is less than the diversity generated by all possible combinations of configurations. Second, the hypothetical case-studies include some that reveal deforestation (D =1) and also others where the outcome does not occur (D = 0). Further, without exception, each configuration is unequivocally associated with one and only one outcome whereas, in practice, each configuration could yield a distribution of cases, some with D=0 and others with D=1. As I show later, this is an important factor that influences the strength of causal inferences. Third, all outcomes are clear-cut: there is no case where the outcome of interest (D) is questionable. This is a radical simplification for, as should be evident from the measurement complications discussed before, it will not be uncommon to find empirical instances where the true outcome is difficult to assess.

To avoid excessive cluttering we adopt the following notational convention: if any condition, say condition L, attains value 1, we use the capital letter that identifies the condition, L. On the other hand, if L=0 then we symbolize this event by using the small case letter l. In addition we use the symbol '^' for the Boolean operator for intersection of sets ('and') and '+ 'to symbolize the Boolean operator for union of sets ('or'). Thus, for example, the Boolean expression {<L^R> + <T^r>} indicates the occurrence of two sets of conditions: land inequality (L) and high population pressure (R) or ill-defined property titling (T) in the absence of population pressure (r). Finally, the Boolean expression {D=<L^R>+<T^r>} indicates that deforestation occurs, (D), either in the presence of land inequality and high population pressure OR when no population pressure is accompanied by ill-defined titling of property.

Very simple principles of reduction applied to the table of data can be used to determine prime implicants and then to obtain a parsimonious expression for the outcome of interest, namely D. These principles do not take into account the frequency with which each combination of conditions occurs, only their empirical occurrence: one occurrence is as potent to establish a combination of conditions as five may be. In the hypothetical example described above the most parsimonious description of the conditions leading to D is as follows:

$$\{D= L\wedge R + T\wedge r\} \qquad (3)$$

According to (3), population pressure is neither a necessary nor a sufficient condition for deforestation to occur: population growth only matters if it occurs in conjunction with land inequality. Instead, distorted titling legal codes and policies lead to deforestation even in the absence of population pressures of any sort.

2. **Analysis of case-studies of deforestation.**

a. *Sampling principles.*

Our search for case-studies to perform qualitative analysis followed the same principles stated before for the meta-analysis. First we located review studies and then we applied the ascendant and descendant methods. In a second stage we used citations that appeared in the more prominent journals in the area. In all we were able to gather 55 studies. We then applied systematically three exclusionary principles:

i. first, we excluded studies that were purely descriptive, too general, or only cursory summaries of quantitative information;

ii. we also excluded all studies that were multiple reportings of the same main study but appearing in different publications. In these cases an attempt was made to maximize the amount of information supplied in the various versions of the study;

iii. Finally, we excluded studies where the extent of deforestation or population growth was assessed only informally, using reports from others or what appear to be uncorroborated guesses of the investigators.

The 38 studies that remained in the sample were all in-depth analyses of one or a few countries, areas, or villages/districts. There is a fair representation of all the developing regions where deforestation seemingly is or could become a problem. In all these studies attempts were made to assess the extent of deforestation using either official statistics based on topographical maps or special surveys, aerial photography or satellite imagery. The magnitude of population pressures (growth and density) was measured from official statistics. Most of the studies identify other causal factors that appear to trigger rapid deforestation. However, in only a handful of studies is there a precise assessment of the nature of all these factors. In most studies there is a blend of factors that are brought to bear, some of which are merely identified as being present (or absent) from examination of secondary sources, interviews, or direct observation by the researcher whereas others are more precisely characterized.

b. *The pitfalls of the sample of case-studies.*

Our final sample of case-studies is prone to some of the same errors that were described in Section III and to some new ones as well. In particular, unidentified studies could disproportionately represent instances of only one type of relation between the various causal factors and deforestation. Unlike the situation faced in meta-analysis, however, there is no well-defined procedure of gauging the extent of the problem. As we indicate below, it is likely that our sample is somewhat biased but in ways that are impossible to correct with the tools available to us. The only solution to this problem is to formulate a study from scratch where deforestation and non-deforestation are possible outcomes of a set of causal conditions of interest.

Unlike case studies dealing with revolutions or strikes where the occurrence of the event is never in doubt, case studies of deforestation begin on an ambiguous note: the degree or even the existence of deforestation is not always well established. An important consequence of this ambiguity is that one may obscure outcome differences that could be revealing of the types of human activities and social institutions that are involved. An analogous but distinct ambiguity is related to what we refer to as the intensity of deforestation. As discussed before, different **types** of deforestation cause different degrees of damage to the ecosystem: the wholesale destruction of a tropical forest to gather a few cubic meters of precious round wood cannot be assigned the same status as equivalent areas (volume) deforested through the collection of fuelwood for the simple reason that their implications for sustenability and regeneration are totally different. In virtually no study was there a direct attempt to qualify the intensity of deforestation. To mitigate somewhat the effects of this uncertainty we classified the studies according to the dominant type of activity implicated in the clearing of forests. Although admittedly the correlation between long-term environmental implications and type of activities leading to deforestation is far from tight, explicit control for the latter should reduce potential biases. Table 3 contains information on the immediate causes of deforestation and, in addition, on the geographic area of the study and the source used for the assessment of deforestation.

{Table 3 about here}

An additional difficulty presented by case studies is the recurrent presence of ambiguities in what can be referred to as time and space lags. Although the timing of events may be unquestionable, the precise lags are rarely well-defined. For example, if titling policies are convincingly implicated in the acceleration of the rate of deforestation one will not always know from the case-studies themselves what was the time elapsed between implementation of the policies and the initiation of the acceleration. 'Space lags' are even more difficult to pin down. 'Space lags' occur when a local outcome, such as clearing of dense tropical forests, follows as a consequence of events that take place elsewhere, such as excess growth of the labor force in some urban areas. Naturally, these two ambiguities not only surround in-depth case studies but are also responsible for weaknesses in more conventional cross-sectional analyses.

Perhaps the most troublesome feature of the case-studies is that all of them identify an instance of deforestation (or D=1). We did not include case-studies examining a case of no-deforestation (D=0). To be sure, there was some variability in the 'gravity' of forest clearing but, for the most part, the distinction was qualitative and informal and we made no attempt to use it. The result is that we are left with a set of observations that have been seemingly sampled on the dependent variable so that only those with D=1 are included. We simply do not know the extent to which the same combination of conditions that yields a 'positive' (D=1 or deforestation) outcome also leads, in other contexts, with other units of observation, to a 'negative' (D=0 or no-deforestation) outcome. This limits the usefulness of the inferences since we will not be in a position to provide solid tests of internal validity. Strictly speaking, Boolean expressions for 'positive' outcomes could be manipulated and translated into Boolean expressions for the 'negative' outcomes. And unless we are able to observe the realization of both positive and negative outcomes we will not be able to assess the exact boundaries within which our inferences apply. Our results will hold true only if the (unaccounted) cases of 'negative' outcomes represent a lower proportion than those of 'positive' outcomes **for each** combination of conditions that contributes to the formulation of causal statements. To limit the damage that this problem creates, we use a series of experiments to establish inferences with minimum associated errors.

c. *Data reduction.*

Before attempting to draw inferences from the case-studies in the sample, we identify a set of conditions which, in alternative combinations, are attributed important influence on the likelihood of deforestation. What follows is a brief description of these conditions. In our quest toward simplification we have reduced the set so that each of the elements contained in it can attain only two values depending on whether it is present or absent. Although this may do injustice to the richness of the case studies, it is an almost unavoidable simplification to enhance parsimony while simultaneously illustrating the application of the procedure.

c.1. Population pressure (R).

Attains a value 1 if there is evidence of rapid population growth or high population density in urban or rural areas or both and 0 otherwise.

c.2. Unequal distribution of land (L).

L attains a value of 1 if there is evidence of a highly skewed distribution of land for cultivation and 0 otherwise. Excessive land fragmentation and the resulting decreasing yields and sheer landlessness are at the root of shifting cultivation that progresses at the expense of forests or that literally follows the tracks left by the logging industry into low fertility soils. Landlessness and fragmentation are partly the outcome of differential population growth but they are also the direct result of preservation of land tenure regimes biased toward inefficient latifundia and large cattle ranches.

c.3. Unequal access to credit, technology and markets (C).

We say that C is present in social contexts where small proprietors have little or no access to credit for investment in factors of production to increase yields (fertilizers, pesticides), or when they have difficult or no access to technological innovations such as irrigation and mechanization of operations or, finally, when commercialization of the products is restricted by lack of control over transportation, storage and pricing mechanisms. If at least one of the three conditions is satisfied then C=1. Otherwise C attains a value of 0.

c.4. Titling policies (T).

The variable T attains the value 1 when there is evidence of allocation of property to small cultivators under rules or codes that prevent direct appropriation of the land and its full use in commercial transactions. Under these conditions title over property may be gained only after direct and extensive use (clearing) but it may not include provisions to enable the cultivator to offer it as collateral. Thus, while the legal proprietor may have rights of use, he has no claim to rights of exchange. Faulty titling policies have been blamed for eroding incentives to apply proper conservation management and for actually promoting (making rational) the indiscriminate exploitation of the natural resource base.

c.5. Biased government policies (G).

This is a complex dimension under which we include several conditions that, in very thorough studies (see for example Repetto, 1988; Repetto and Gillis, 1988), are kept strictly separate. G attains a value of 1 if one of the following conditions exist:

i) Central government policies of rent recovery, royalties and tax incentives that grossly undervalue the current and future discounted value of forest assets.

ii) Central government policies granting subsidies and tax exemptions for the exploitation of forests for production geared to export markets. These subsidies and tax exemptions make profitable for individual proprietors operations that are socially unprofitable.

iii) Inappropriate investments or incentives for the design and implementation of proper management for conservation.
iv) Misguided settlement policies that reshuffle labor force with no or only scarce provision for the socially rational exploitation of forest lands.

Admittedly, this is a highly stylized 'reduction' of conditions that are invariably more complex and difficult to disentangle. Take as a first example the case of government policies. The dimensions that we chose to include here do not distinguish between two very different though connected types of actions. Actions in the first type operate through juridical interference of central governments that transform a common-property resource into a public resource and in so doing inevitably undermine traditional rights over forest resources and, consequently enhancing problems of open-access to common property. The second type of actions are flawed valuation of resources that precedes or accompany the implementation of investment incentives, credit concessions, tax and royalty provisions designed to generate immediate material gains in the form of tangible returns or by alleviating pressure over land.

A second example is the case of unequal distribution of land. Cases of inequality may differ widely among one another. Even if one were able to standardize for the degree of land inequality, there remains the possibility that fertility of the soil, predominant type of production, optimal factor inputs combination, and division of labor will accentuate or attenuate the effects of skewed property distribution. As suggested before, community and household-level mechanisms, possibly including the role of women and children, may serve to temporarily alleviate the consequences of population pressure or, equivalently, of land fragmentation in highly unfair and inflexible property regimes.

Furthermore, the logical status of these conditions is not identical. Some are mediating factors (for example L) whereas others operate as contingencies (for example T). Similarly, the verification of the presence (absence) of any one of them from examination of case-studies reports is seldom straightforward. Two factors that may appear to be identical in several studies may be, in reality, sufficiently different to require different categories. But although the conceptualization may not be as rigorous as we would like, it will suffice if our aim is only to highlight the role that these factors play in the production of the outcome of interest (deforestation) rather than producing a correct explanation for it.

Finally, an additional data reduction issue needs to be discussed and clarified. To be consistent with our previous discussion we should introduce a distinction between types of deforestation. Indeed, the most immediate activities that lead to the clearing of forest not only have different impact on the ecosystem but are themselves the results of heterogeneous processes. In keeping with this conjecture to which we assigned a prominent role in our previous discussion, we classify the activities into four types: clearing by landless peasants and small landholders for subsistence production or for monocultivation (cash crops for export markets); clearing for the operation of large cattle ranches or for extensive cultivation of one or two products; clearing for woodfuel and charcoal manufacturing; clearing for logging. These will be referred to as D(1), D(2), D(3) and D(4) respectively. The descriptions contained in each case study contain remarkable imprecision on this issue. With a few exceptions, deforestation is always attributed to a combination of two or more deforestation activities but without ever assigning prominence to any one of them. If our conjecture is correct, this ambiguity in the description of the outcome can only obscure the causal analysis.

d. *Deforestation as the outcome of complex sets of causal factors.*

Table 4 displays the results of reducing the data from the case-studies into a form suitable for the application of qualitative algebra.

Applications of simple rules of Boolean algebra lead to the following causal statements describing each of the outcomes:

$$\{D(1)=\langle G\wedge(l\wedge c\wedge t\wedge r)\rangle+\langle R\wedge(c\wedge g\wedge t)\rangle+\langle (R\wedge G)\wedge(l\wedge c)\rangle+ +\langle (R\wedge L\wedge C)\wedge(g)\rangle+\langle (R\wedge L\wedge G)\wedge(t)\rangle\} \tag{4a}$$

$$\{D(2)= \langle (R\wedge L)\wedge(c\wedge g\wedge t)\rangle+\langle G\wedge(l\wedge c\wedge t\wedge r)\rangle\} \tag{4b}$$

$$\{D(3)= \langle R\wedge(c\wedge g\wedge t)\rangle+\langle (R\wedge G)\wedge(lc)\rangle+\langle (R\wedge L\wedge C)\wedge(g)\rangle\} \tag{4c}$$

$$\{D(4)= \langle (R\wedge L)\wedge(c\wedge t)\rangle+\langle (R\wedge G)\wedge(l\wedge c\wedge t)\rangle+\langle G\wedge(r\wedge l\wedge c)\rangle\} \tag{4d}$$

The first feature of the expressions that deserves comments is that D(1), D(2), and D(4) are outcomes that can obtain in the absence of population growth. In the other case, D(3), deforestation only occurs if there is detectable population pressure. This should not be surprising since, as remarked before, the relation between woodfuel consumption and population growth is perhaps more straightforward and direct than all others.

The second feature is that population pressure alone (in the absence of the other factors) can by itself produce only outcomes D(1) and D(3). In all the other cases population pressure must act in conjunction with either L, T, or G to generate deforestation. The third feature is that, as hypothesized, the conjunction of causal mechanisms leading to deforestation is not identical across outcomes and that a single causal representation is insufficient to capture all the processes. Note for example that government policies can by themselves generate D(4), even in the absence of any of the other conditions, but that this is insufficient to generate other outcomes.

Finally, in addition to R the two pivotal conditions across outcomes are government policies (G) and land inequality (L). Titling policies does not appear to be necessary when other conditions are present and access to credit seems to play a minor role throughout.

e. *Flaws of the analysis: multiple outcomes and the occurrence of non-deforestation.*

A potentially serious problem is that the case-studies did not establish a one-to-one correspondence between types of deforestation and sets of causal conditions. Thus, in those cases where more than one type of outcome was detected, the explanatory argument was focused on the dominant type of outcome only, not on the secondary ones. Instead, Table 4 was constructed including all outcomes detected in the study and associating them with the causal configuration invoked to explain the dominant outcome, if no other was given. The consequence of this is that Table 4 may overrepresent the causal configuration for a particular outcome. Thus, for example, the configuration of conditions for D(4) may be overdetermined in the sense that some of them are included merely because D(4) occurred simultaneously with, say, D(1), not because they are necessary for D(4) to occur. To check on the effects of this reconstruction, we prepared a different table of truth in which only dominant outcomes were represented. The results of the analysis of that table are only trivially different from the ones already presented and are not examined further.

What about the impact of cases of non-deforestation?

We begin the discussion of this issue with a clarification. The problem that we allude to is generated not by excluding cases where the outcome is reforestation of degraded territories. Indeed, reforestation belongs to a different class of phenomena that requires an idiosyncratic explanation; it is simply not an outcome alternative to deforestation. The difficulty is a subtler one since it is rooted in a possibly non-empty set of cases where a particular causal configuration in Table 4 does not lead to deforestation. Suppose, for example, that through an experimental design or through detailed historical investigation we ascertain that the configuration represented by Case I in Table 4 is associated not only with 14 cases of D(1)=1 but with 14 cases of D(1)=0. Leaving aside for the moment the fact that the endeavor that would lead to such finding may be impossible to undertake, one may well ask what would be the outcome associated with the causal configuration? Perhaps, the simplest solution is to neglect it since its probable outcome is questionable. Less problematic would be the case in which the same difficult endeavor unearthed not 14 but only 2 cases of non-deforestation. On pure probabilistic grounds, one would be on safe grounds associating to Case I the response D(1) =1.

It follows that Table 4 leads to the selection of explanations that may be highly sensitive to the occurrence of non-deforestation. This is because we implicitly assume that there is no causal configuration where the frequency of 'negative' outcome (non-deforestation) is larger than or equal to the frequency of cases of deforestation. To assess the nature of the potential bias we repeated the analysis using only those causal configurations in which there were more than 10 combined cases of deforestation and excluded those that were represented by a very small number of cases. To make the exercise feasible, we disregard the distinction between the various outcomes and consider only a generic one, namely D. Only the first three causal configurations in Table 4 are coded D=1; all the others are coded D=0. The explanation inferred from the new coding scheme lends more emphasis to the role of population growth in that it supports the idea that deforestation (D =1) does not occur in its absence although its presence does not always lead to the outcome. The explanation, however, is much less supportive of or illuminating about the role of other factors.

V. Summary and Conclusion.

The application of two relatively new procedures to the analysis of the relation between deforestation and population pressure reveals that while population pressure is an important force leading to deforestation, it rarely acts alone to produce the outcome. Other determinants appear to be necessary as mediation and contingencies for population growth (or density) to have a discernible impact.

The quantitative analysis suggested that even if the effects of population growth are statistically significant, their magnitude is quite modest. And this is a conservative conclusion for the sample of studies that we examined is likely to be biased against the null hypothesis of no relation. In addition, none of the studies included in our sample incorporated factors that our qualitative analysis showed to be strategic and none of them supplied adequate information about outliers.

The qualitative analysis made possible the identification of important social institutions that create an environment where population pressure may or may not affect deforestation or, alternatively, through which population pressure could affect the rate of deforestation. The very tentative analysis that we performed suggests the usefulness of separating types of deforestation and points to the importance of government policies, land distribution and access to credit and technology. But this type of analysis has important limitations, particularly with regard to the inability to observe 'negative' outcomes and their associated causal configurations.

Meta-analysis is limited by the power of the quantitative studies that yield the hypothesis tests: if simple quantitative models are not fit to represent the relations, then meta-analysis will produce little of value. Similarly, the application of qualitative algebra is only as powerful as the case studies themselves: imprecise characterization of outcomes, sloppy conceptualization and measurement of conditions, and poor identification of factors will, in one way or another, affect the set of propositions that can be derived. This suggests that better designed quantitative and qualitative studies incorporating some of the factors identified here are necessary before meta-analysis and qualitative algebra could yield optimal results.

Table 1: Basic Results of Meta-Analysis[1].

Study D	Statistic	N	Sig	C	P	Z	p	Z_{Fisher}	r^2	
1	t=1.48(34)	39	+	1	0	1.45	.074	.25	.07	.51
2	t=1.79(20)	25	+	1	0	1.70	.044	.39	.14	.80
3	t=.53(34)	39	+	1	1	.520	.300	.10	.01	.18
4	t=.04(20)	25	-	1	1	-.04	.510	-.01	-.00	-.02
5	t=6.20(8)	11	+	0	1	3.63	.000	1.53	.83	4.40
6	t=5.14(28)	36	+	1	0	4.27	.000	.87	.49	1.94
7	t=3.98(28)	36	+	1	0	3.51	.000	.70	.36	1.50
8	t=.00(7)	10	+	0	1	.000	.50	.00	.00	.000 [2]

Results of Combined Analysis (Weighted)[3]

Z= 5.20, p=.000
Fail Safe Number =75

Z_{Fisher} = .43
r^2 = .41
D = .89

Key to symbols:

a) The numbers in parentheses are the degrees of freedom.
b) N is the number of observations.
c) Sig is the direction of the effects. A '+' indicates that population pressure increases deforestation.
d) C equals 1 if the model uses appropiate controls.
e) P equals 1 if the model uses population growth rather than density.
f) Z is the Z value corresponding to the observed statistic (first column)
g) p is the level of significance for the observed statistic.
h) r^2 is the square of the correlation coefficient.
i) D is the measure of intergroup distance or effect associated with the observed statistic.
j) Z_{Fisher} is equal to .5(ln (1+r)/(1-r)).

Footnotes to Table 1:

(1) The bibliographic references for the quantitative studies can be found in the list of references. The identifying numbers are the following: 1, 3, 58, 62.

(2) In case 8, the report does not present sufficient statistical information. We have adopted a conservative strategy and inputed a t value of .00.

(3) The weights used are the respective sample sizes.

Table 2: Specialized Results of Meta-Analysis.

Panel 1: Diffuse Comparisons of Significance and Size of Effects.

a) Chi-Square for Significance Levels = 20.74 p= .004

b) Chi-Square for Size Effects = 28.92 p= .000

Panel 2: Focused Comparison Using C and P as Stratifying Criteria.

a) Strata I: with C = 1		Strata II: with C = 0
Z=	4.66	2.56
p=	.000	.001
Z_{Fisher}=	.38	.76
r^2=	.13	.41
D =	.78	1.68

b) Strata III: with P = 1		Strata IV: with P = 0
Z=	2.05	5.46
p=	.019	.000
Z_{Fisher}=	.40	.54
r^2 =	.15	.25
D =	.83	1.15

Panel 3: Imposing a Linear Structure on the Data.

a) Use of C as a predictor:

Best Line for D is : 2.19-1.7378*C and corrrelation is -.43.
Z for Size of Effects is .10 and p=.45

b) Use of P as a predictor:

Best line for D is : 1.18-.05*P and correlation is -.09.
Z for Size of Effects is .85 and p=.19

Table 3: Summary of selected characteristics of case-studies[1]

Characteristics	Frequency (Number of Studies)
a. Region/Area:	
Himalayas (Nepal)	6
Central America	2
Brazil (Amazons)	5
Sub-Saharan Africa	8
Andean Regions	2
Philippines, Indonesia and Thailand	9
Others (Thailand, China, India, Pakistan and Haiti)	6
b. Assessment of deforestation	
Aerial Surveys	2
Topographical Maps-Surveys	17
Landsat	8
Not mentioned	11
c. Types of deforestation	
D(1)	35
D(2)	5
D(3)	18
D(4)	11

Footnotes to Table 3:

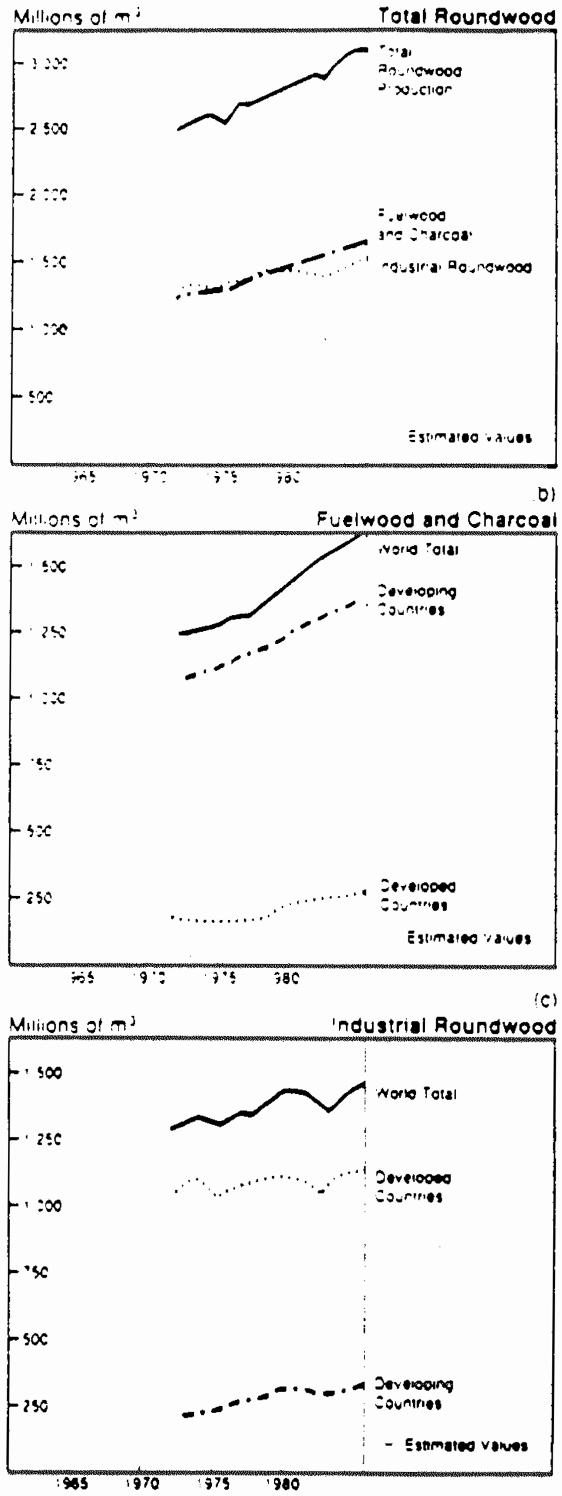
(1) The sources for the case studies appear in the list of references. The identifying numbers are the following: 2, 6, 7, 15, 16, 17, 19, 20, 22, 23, 26, 27, 30, 31, 32, 33, 36, 39, 40, 42, 43, 44, 45, 47, 50, 60, 61, 66, 67, 68, 69, 71.

Table 4: Distribution of Conditions for Sample of Case-Studies

Case	Condition					Outcomes and Frequencies			
	R	L	C	G	T	D(1)	D(2)	D(3)	D(4)
I	1	0	0	0	0	1(14)	1(0)	1(11)	1(0)
II	1	1	0	0	0	1(6)	1(3)	1(2)	1(1)
III	1	0	0	1	0	1(6)	1(0)	1(2)	1(3)
IV	1	0	0	1	1	1(1)	1(0)	1(1)	1(0)
V	1	1	1	0	0	1(1)	1(0)	1(1)	1(1)
VI	1	1	1	0	1	1(2)	1(0)	1(2)	1(0)
VII	1	1	0	1	0	1(2)	1(0)	1(0)	1(2)
VIII	1	1	1	1	0	1(1)	1(0)	1(1)	1(1)
IX	0	0	0	0	1	1(1)	1(0)	1(1)	1(1)

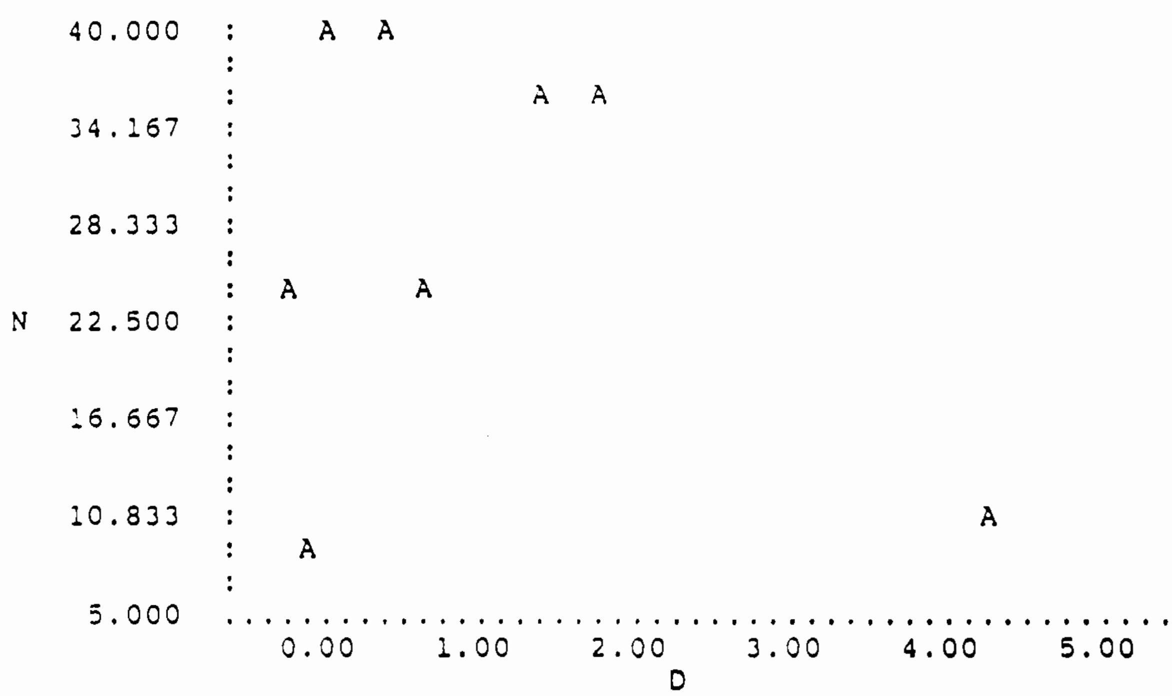
Note: The numbers in parentheses are the frequencies of cases for the corresponding outcome. See text for a definition of symbols.

Figure 1: Time Series of Fuelwood and Charcoal Production.



Source: Taken from Williams, M. (1989). "Forests" in B.L. Turner, W.C. Clark, R.W. Kates et al., (eds.) **The Earth as Transformed by Human Action**, Cambridge: Cambridge University Press.

Figure 2: Funnel Plot of Effect Size (D).



References

1. Allen, J.C. and Barnes, D. (1985). The Causes of Deforestation in Developing Countries. **Annals of the Association of American Geographers** 75(2):163-184.

2. Anderson, D. (1987). **The Economics of Afforestation. A Case Study in Africa**. Baltimore: The Johns Hopkins University Press.

3. Arcia, G., Bustamante, G. and Paguay, J. (1991). URBIQUITO: Un analisis de la relacion entre poblacion y medio ambiente. Quito: Direccion de Planificacion, I. Municipio de Quito.

4. Barbier, E.B., Burguess, J.C. and Markandya, A. (1990). The Economics of Tropical Deforestation, **AMbio** 20(2):55-58.

5. Barrows, C.J. (1991). Land Degradation. **Development and Breakdown of Terrestrial Environments.** Cambridge: Cambridge University Press.

6. Bautista, G. M. (1990). The Forestry Crisis in the Philippines: Nature, Causes, and Issues. **The Developing Economies** 28(1):67-94.

7. Bee, O.J. (1987). Depletion of the Forests Resources in Philippines. Field Report Series No. 18. Manila: Institute of Southeast Asian Studies.

8. Bilsborrow, R. (1992). Population Change and Agricultural Intensification in Developing Countries. Paper presented at the SSRC/DAWN/ISC Workshop on Population and the Environment, Cocoyoc, Mexico, January 28-February 1st, 1992.

9. Biswas, A.K. (1986). Land Use in Africa. **Land Use Policy** 3(4):247-259.

10. Blaikie, P. and Brookfield, H. (1987a). Questions from the History in the Mediterranean and Western Europe. In **Land Degradation and Society**, eds. P. Blaikie and H. Brookfield, London and New York: Methuen.

11. Blaikie, P. and Brookfield, H. (1987b). Approaches to the Study of Land Degradation. In **Land Degradation and Society**, eds. P.Blaikie and H. Brookfield. London and New York: Methuen.

12. Bowonder, B. (1985). Deforestation in Developing Countries, **Journal of Environmental Systems** 15 (2):171-191.

13. Bremer, J. (1984). Fragile Lands: A Theme Paper on Problems, Issues, and Approaches for Development of Humid Tropical Lowlands and Steep Slopes in the Latin America Region. Washington D.C.: Development Alternatives, Inc.

14. Budowski, G. (1982). Socio-Economic Effects of Forest Management on the Lives of People Living in the Area: The Case of Central America and Some Caribbean Countries. In **Socio-Economic Effects and Constraints in Tropical Forest Management**, ed. E.G. Hallsworth. New York: John Wiley and Sons, Ltd.

15. Chattopadhyay, S. (1985). Deforestation in Parts of Western Ghats Region (Kerala), India, **Journal of Environmental Management** 20:219-230.

16. Collins, J.L. (1986). Smallholder Settlement of Tropical South America: The Social Causes of Ecological Destruction, **Human Organization** 45(1):1-10.

17. Collins, J.L. and Painter, M. (1986). Settlement and Deforestation in Central America: A Discussion of Development Issues. Working Paper 31. Washington D.C.: Cooperative Agreement on Human Settlement and Natural Resources System Analysis.

18. Denevan, W.M. (1982). Causes of Deforestation and Forest and Woodland Degradation in Tropical Latin America. Washington D.C.: U.S. Office of Technology Assessment.

19. Diaz, C.P. (1982). Socio-Economic Thrusts in an Integrated Forest Management System: The Philippine Case. In **Socio-Economic Effects and Constraints in Tropical Forest Management**, ed. E.G. Hallsworth. New York: John Wiley and Sons, Ltd.

20. Donner, W. (1987). **Land Use and Environment in Indonesia**. Honolulu: University of Hawaii Press.

21. Eckholm, E. (1976). **Losing Ground. Environmental Stress and World Food Prospects**. New York: W.W. Norton and Company, Inc.

22. Eckholm, E. (1979). Planting for the Future: Forestry and Human Needs. Worldwatch Paper 26. Washington D.C.: Worldwatch Institute.

23. Eder, J.F. (1990). Deforestation and Detribalization in the Philippines: The Palawan Case. **Population and Environment** 12(2):99-115.

24. FAO (1986a). Natural Resources and the Human Environment for Food and Agriculture in Africa. Environment and Energy Paper 6. Rome: FAO.

25. FAO (1986b). **African Agriculture: The Next 25 Years.** Annex II. The Land Resource Base. Rome: FAO.

26. Feeny, D. (1988). **Agricultural Expansion and Forest Depletion in Thailand, 1900-1975**. In World Deforestation in the 20th Century, eds. J.F. Richards and R.P. Tucker. Durham: Duke University Press.

27. Fleming, W.M. (1983). Phewa Tal Catchment Management Program: Benefits and Costs of Forestry and Soil Conservation in Nepal. In **Forest and Watershed Development and Conservation in Asia and the Pacific**, ed. L.S. Hamilton. Boulder: Westview Press.

28. Ghildyal, U.C. (1979). The People and the Forests. In **Man and the Forests in India**, eds. K. M. Gupta and D. Bandhu. New Delhi: Today and Tomorrow Printers and Publishers.

29. Ghosh, R.C. (1982). Socio-Economic Effects and Constraints in Forest Management. In **Socio-Economic Effects and Constraints in Tropical Forest Management**, ed. E.G. Hallsworth. New York: John Wiley and Sons, Ltd.

30. Goucher, C.L. (1988). The Impact of German Colonial Rule on the Forests of Togo. In **World Deforestation in the 20th Century**, eds.J.F. Richards and R.P. Tucker. Durham: Duke University Press.

31. Hall, A.L. (1989). **Developing Amazonia. Deforestation and Social Conflict in Brazil's Carajas Programme.** Manchester: Manchester University Press.

32. Hallsworth, E.G. (1982). The Human Ecology of Tropical Forest. In **Socio-Economic Effects and Constraints in Tropical Forest Management**, ed. E.G. Hallsworth. New York: John Wiley and Sons, Ltd.

33. Hosier, R.H. (1988). The Economics of Deforestation in Eastern Africa, **Economic Geography** 64(1):121-136.

34. International Institute for Environment and Development and World Resources Institute (1986). **World Resources 1986**. New York: Basic Books.

35. Ives, J.D. (1987). The Theory of Himalayan Environmental Degradation: Its Validity and Application Challenged by Recent Research, **Mountain Research and Development** 7:189-199.

36. Ives, J.D. (1988). Development in the Face of Uncertainty. In **Deforestation: Social Dynamic in Watershed and Mountain Ecosystem**, eds. J. Ives and D.C. Pitt. London: Routledge.

37. Ives, J. and Messerli, B. (1989). **The Himalayan Dilemma. Reconciling Development and Conservation.** London: Routledge.

38. Kaul, S. K. (1979). Human Aspects of Forest Development. In **Man and the Forests in India**, eds. K. M. Gupta and D. Bandhu. New Delhi: Today and Tomorrow Printers and Publishers.

39. Khattak, G.M. (1983). The Watershed Management Program in Mansehra, Pakistan. In **Forest and Watershed Development and Conservation in Asia and the Pacific**, ed. L.S. Hamilton. Boulder: Westview Press.

40. Kleinert, C. (1987). Settlement Pressure and the Destruction of the Forest in Rwanda (Eastern Central Africa), **Applied Geography and Development** 29:93-105.

41. Lele, U. and Stone, S.W. (1989). Population Pressure, the Environment and Agricultural Intensification. Variations on the Boserup Hypothesis. MADIA Paper 4. Washington D.C.: The World Bank.

42. Lundahl, M. (1979). **Peasants and Poverty. A Study of Haiti**. (Chapter 5: Erosion.) New York: St. Martin's Press.

43. Lundgren, B. and Lundgren, L. (1982). Socio-Economic Effects and Constraints in Forest Management: Tanzania. In **Socio-Economic Effects and Constraints in Tropical Forest Management**, ed. E.G. Hallsworth. New York: John Wiley and Sons,Ltd.

44. Martens, J. (1983). Forests and Their Destruction in the Himalayas of Nepal. Miscellaneous Paper 35. Kathmandu: Nepal Research Centre.

45. McNeil, J.R. (1988). Deforestation in the Araucaria Zone of Southern Brazil, 1900-1983. In **World Deforestation in the 20th Century**, eds. J.F. Richards and R.P. Tucker. Durham: Duke University Press.

46. McNicoll, G. (1990). Social Organization and Ecological Stability under Demographic Stress. Working Paper, Center for Policy Studies, The Population Council.

47. Morgan, W. B. and Moss, R.P. (1972). Savanna and Forest In Western Nigeria. In **People and Land in Africa South of the Sahara**, ed. M. Prothero. New York: Oxford University Press.

48. Mullen, B. (1989). **Advanced BASIC Meta-Analysis**. Hove and London: Lawrence Erlbaum Associates.

49. Myers, N. (1980). Deforestation in the Tropics: Who Gains, Who Loses. In **Where Have All the Flowers Gone?** Deforestation in the Third World, ed. Department of Anthropology. Williamsburg: College of William and Mary.

50. Osenobo, G.J. (1988). The Human Causes of Forest Depletion in Nigeria, **Environmental Conservation**, Vol 15 (1):17-28.

51. Postel, S. (1984). Protecting Forests. In **State of the World 1984**, ed. Worldwatch Institute. New York: W.W. Norton and Company.

52. Ragin, Ch. (1987). **The Comparative Method: Moving beyond Qualitative and Quantitative Strategies.** Berkeley: University of California Press.

53. Regional Office for Asia and the Pacific (RAPA) and FAO (1989). **Environmental Problems Affecting Agriculture in Asia and Pacific Region (World Food Symposium).** Rome: FAO.

54. Repetto, R. and T. Holmes (1983). The Role of Population in Resource Depletion, **Population and Development Review** 9(4):609-632.

55. Repetto, R. and M. Gillis (1988). **Public Policies and the Misuse of Forest Resources.** Cambridge: Cambridge University Press.

56. Repetto, R. (1988). The Forest for the Trees? Government Policies and the Misuse of Forest Resources. Washington, D.C.: World Resources Institute.

57. Rosenthal, R. (1979). The 'File Drawer Problem' and Tolerance for Null Results, **Psychological Bulletin** 86:638-641.

58. Rudel, T.K. (1989). Population, Development, and Tropical Deforestation: A Cross-National Study, **Rural Sociology** 54(3):327-338.

59. Schram, G. (1987). Managing Urban/Industrial Woodfuel Supply and Demand in Africa. **The Annals of Regional Science,** Vol 21(3):60-79.

60. Singh, J.S., V. Pandey and A.K. Tiwary (1984). Man and Forests: A Central Himalayan Case Study. **Ambio,** Vol 13(2):80-87.

61. Smil, V. (1983). Deforestation in China, **Ambio Xii** (5):226-231.

62. Southgate, D., Sierra, R. and Brown, L. (1989). **The Causes of Tropical Deforestation in Ecuador: A Statistical Analysis.** Ohio State University.

63. Stonich, S. (1989). The Dynamics of Social Processes and Environmental Destruction: A Central American Case Study, **Population and Development Review** 15 (2):269-296.

64. Sutlive Jr., V. H. (1980). Introduction. In **Where Have All the Flowers Gone? Deforestation in the Third World,** ed. Department of Anthropology. Williamsburg: College of William and Mary.

65. Thiesenhusen, W.C. (1991). Implications of the Rural Land Tenure System for the Environmental Debate: Three Scenarios, **Journal of Developing Areas** 26(Oct):1-24.

66. Thompson, M. and Warburton, M. (1988). Uncertainty on the Himalayan Scale. In **Deforestation: Social Dynamic in Watershed and Mountain Ecosystem**, eds. J. Ives and D.C. Pitt. London: Routledge.

67. Thomson, J.T. (1988). Deforestation and Desertification in 20th Arid Sahalian Africa. In **World Deforestation in the 20th Century**, eds. J.F. Richards and R.P. Tucker. Durham: Duke University Press.

68. Tucker, R.P. (1988). The British Empire and India's Forest Resources: The Timberland of Kumoan and Assam, 1914-1950. In **World Deforestation in the 20th Century**, eds. J.F. Richards and R.P. Tucker. Durham: Duke University Press.

69. Westoby, J. (1989). **Introduction to World Forestry**. London: Basil Blackwell.

70. Whitney, J.B.R. (1987). Impact of Fuelwood Use on Environmental Degradation in the Sudan. In **Lands at Risk in the Third World: Local-Level Perspectives**, eds. P.D. Little and M.M. Horowitz, with A.E. Nyerges. Boulder and London: Westview Press.

71. Whitlow, J.R. (1980). Deforestation in Zimbabwe: Problems and Prospects. Supplement to **Zambezia**. Salisbury: University of Zimbabwe.

72. Williams, M. (1989). Deforestation: Past and Present, **Progress in Human Geography** 13(2):176-208.

73. Williams, M. (1990). Forests. In **The Earth as Transformed by Human Action**, eds. B.L. Turner, W. C. Clark, R.W. Kates, et al., Cambridge: Cambridge University Press.

74. World Resources Institute, International Institute for Environment and UNEP (1991). World resources 1990-1991: Forest and Rangelands. New York: Basic Books.

75. World Resources Institute, World Bank and UNDP (1985). **Tropical Forests: A Call for Action. (Part I: The Plan)**. Washington D.C.: World Resources Institute.

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