Spatial Variability and Disincentives to Harvest: Deforestation and Fuelwood Collection in South Asia

Gunnar Köhlin and Peter J. Parks

ABSTRACT. *A major strategy to combat deforestation caused by household fuel collection has been the establishment of plantations, especially in India. A household model is specified with a number of collection possibilities and analyzed empirically using household, vegetation, and GIS data, and the potential decrease in collection from the natural forest is estimated. The results show reduced pressure on the natural forest due to the establishment of plantations. It also questions buffer zone plantations very close to natural forests.* (JEL Q23)

Regional and country-level trends in deforestation result from decisions made at smaller spatial scales. At the household level, decisions that lead to deforestation can be considered land use decisions. Recent advances in spatial modeling of land use decisions have had much success after including location of land use choices in analyses. Interest in, and examples of spatial models applied to tropical forests is growing. Improved regional- and country-level results can be obtained by aggregating smaller analytical units: a spatial model must start with tracts of land whose location is known.

For example, one of the most important reasons for long-term deforestation is the fuel collection decision made by millions of households every day. In the 1970s, dependence on tropical natural forests as a source of fuel led to simplistic models and projections of the growing gap between deforestation and reforestation (so called wood balance or gap models). Such models typically took into consideration population and income growth, but not the possibilities for substitute fuels from planted forests. Planted forests have been used as a major strategy to combat deforestation, especially in India, where the government spent 35 billion Rupees during the 1980s to afforest 13 million hectares.

Unfortunately, some plantation projects were badly implemented. Poor results decreased interest in the potential for planted forests to reduce fuelwood collection in natural forests. However, failing to consider fuelwood collection from natural forests in policy design is a serious mistake that could limit or even prevent the success of policies to combat deforestation in many parts of the developing world.

The majority of households in developing countries depend on biomass for cooking and heat. Scarcity of biomass is likely to lead to continued environmental degradation and ever increasing efforts to find fuel, perpetuating the vicious cycle of deforestation for fuel. Although studies of household fuelwood collection are increasing in number (e.g., Mercer 1991; Amacher, Hyde, and Joshee 1993; Bluffstone 1995; Cooke 1998; and Mekonnen 1999), the potential for plantations to reduce deforestation from fuelwood collection in many developing regions remains unknown.

For example, in the Indian state of Orissa, the Orissa Social Forestry Project (OSFP) was established with external support from Sweden. The OSFP was intended to develop a self-reliant and replicable system of forestry that could be applied in the villages of Orissa, and which would also eventually reduce the pressure on government forests. Unfortunately, it has not yet been possible to

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The authors are, respectively, assistant professor at the Environmental Economics Unit, Department of Economics, Göteborg University, and associate professor at Department of Agricultural, Food, and Resource Economics, Cook College, Rutgers University. The research was supported by the Swedish International Development Cooperation Agency (Sida). The paper has benefitted from comments by Thomas Sterner, Fredrik Carlsson, Alemu Mekonnen, Priscilla Cooke, Ramon Lopez and two anonymous reviewers.

show whether this goal has been met. In evaluations of the OSFP it is alleged that the major environmental benefit from the project is decreased pressure on natural forests as the result of the establishment of 100,000 ha of community plantations. However, no quantitative evidence has been developed.

In contrast, there are those within the Orissa Forest Department who argue that the secure user rights of village woodlots (VWL) may make villagers stay away from the woodlots, that were established (under the OSFP) on land that had earlier provided at least some fuel. If this is true, then the result of establishing these VWL has been increased pressure on government forests, which are exploited under *de facto* open access. These conflicting claims regarding the ability of planted forests to relieve pressure on natural forests can only be resolved through empirical analysis.

Despite the great global interest in deforestation over the last decade, not much has been done to analyze the impact of plantations to reduce deforestation, or on household modeling to explain deforestation. In a recent review of the literature on tropical forest land use, Parks, Barbier, and Burgess (1998) describe only a few studies that focus on the agents of forest land clearing for agriculture and livestock, and that take household characteristics into account. The work of López on agricultural households in Côte d'Ivoire and Ghana (López 1986) is one example. Other comprehensive reviews of the deforestation literature (Lambin 1994; Kaimowitz and Angelsen 1997) give the same result: there are numerous cross-sectional country and province studies, but fewer studies that use household data.

This paper applies a spatial perspective to evaluate deforestation pressures on natural forests and the potential ability of planted forests to relieve these pressures. The policy question considered is: Have plantations reduced the pressure on natural forests?

In order to answer this question the household collection decision must be carefully modeled and empirically estimated. Our strategy is to start from a spatial household model where we specify a number of collection possibilities. These are empirically analyzed using data from Orissa. The collection functions include accessibility of different sources of biomass (location) and household characteristics. Shadow wages for different household categories collecting fuel from different sources of biomass are estimated. These wages are then used to estimate the potential decrease in collection from the natural forest, using a time allocation function for collection in forests at different locations.

Community plantations have been found to provide substantial welfare gains by saving time spent in fuel collection (Köhlin 1998, Chapter 2). These welfare effects depend on spatial considerations. A comparison of villages with and without VWL indicates higher consumption of fuel in the villages with VWL (Köhlin 1998, Chapter 3). The results from this paper show a significant reduction in pressure on the natural forest due to establishment of VWL. The location of the VWL must be considered also in this case, since it must provide a reasonable fuel substitute for fuel from natural forests. The reduction varies between villages and ranges from 0 to 29% of current collection in natural forests (NF). Analysis of the decision to collect shows that the availability and location of VWL influences the probability of collection in NF. The combined effect is evidence that the establishment of plantations has reduced the pressure on the natural forest, but this effect is crucially dependent on location.

There is spatial variation in the different benefits from plantations (time saved, fuel consumed, and decreased extraction from natural forests). The decision to collect in the natural forest is affected by shadow wages from collection in plantation. The shadow wages, in turn, are affected by the distances to planted and natural forests. Plantations can decrease fuelwood collection in natural forests, but this potential depends on distance. Decreased collection in natural forests depends on the location of the planted forest: the effect is non-linear with an inverted U-shape that peaks when planted forests are located around three kilometers from the natural forest. This location is where the household collection decision is most sensitive to changes in relative shadow wages.

These findings argue that the optimal location of plantations depends on the objective of the plantation, but that the popular concept of buffer zone plantations could be less efficient in achieving the environmental objective of decreasing pressure on the forest than plantations a couple of kilometers away from the forest. The paper concludes with a summary of such policy recommendations.

I. A HOUSEHOLD MODEL OF FUELWOOD COLLECTION

The purpose of this model is to explain fuel collection behavior, that is, the choice of collection/consumption of biomass from natural forests, VWL, and the market. The model assumes that households make decisions to maximize utility. Utility is nonseparable due to large subsistence production which makes production and consumption decisions interdependent. This interdependence is a common feature of studies in developing countries, including applications to agriculture (e.g. López 1986; Strauss 1986; Jacoby 1993; Skoufias 1994) and fuel collection (e.g. Amacher, Hyde, and Joshee 1993; Mercer 1991; Cooke 1998; Mekonnen 1999).

The model features a well behaved utility function with fuel consumption (C) as a separate argument together with consumption of a composite purchased good other than fuel (X), leisure (T_L) and household characteristics, A, acting as taste shifters,

$$U = u(C, X, T_L; A). \quad [1]$$

Fuel consumption, C, is derived from natural forests or village woodlots.

Fuel (F_i) can be collected either in natural forest or VWL ($i = N$ and V, respectively). Collection is a function of time input[1] (T_i), household composition (A) and resource availability (R_i). For collection in the natural forest, physical capital (K) in the form of ox and cart can be used. We thus have the following household collection functions:

$$F_i = f_i(T_i, K, A, R_i). \quad [2]$$

These collection functions could also be referred to as production functions for fuelwood.

The decision on whether to collect, sell, or buy fuel also depends on a household monetary constraint where the purchase of commodities (at price p_x) and rental cost of a cart ($p_K K$) must be balanced by the income from fuel sold (the net of fuel production and consumption at price p_F), wage labor (T_w at wage w) and other non-fuel, non-labor income[2] (Y),

$$p_X X + p_K K \leq p_F\,(\Sigma_i F_i - C) + wT_W + Y. \quad [3]$$

Note that this is not the commonly used full-income specification which would also include the value of household labor used for subsistence production and leisure. Instead we use an explicit time constraint where total time (T_T) is the sum of time spent collecting in NF and VWL, time spent working for wages, and leisure,

$$\Sigma_i T_i + T_W + T_L = T_T. \quad [4]$$

Consumption, capital, and time are nonnegative, so that

$$C, X, K, T_i, \mathrm{T}_W, T_L \geq 0. \quad [5]$$

The Lagrangian for the household's[3] utility maximization problem with respect to F_i, C, X, K, T_i, T_W, and T_L is:

$$\begin{aligned} L = {} & u(C, X, T_L; A) + \lambda[p_F(\Sigma_i F_i - C) \\ & + wT_W + Y - p_X X - p_K K] \\ & + \mu[T_T - \Sigma_i T_i - \mathrm{T}_W - T_L] \\ & - \nu[F_{V-} f_V(T_V, K, A, R_V)] \\ & - \varphi[F_N - f_N(T_N, K, A, R_N)], \end{aligned} \quad [6]$$

[1] Time input from different household member categories (men, women, boys, girls) are used in the estimation procedure, but the analysis is carried out at the household level.

[2] The most important sector, agriculture, is only included this way to keep the model simple and in line with the empirical analysis to come. Admittedly, a full model featuring participation decisions in wage labor, agriculture, and collection would be preferable.

[3] With collection aggregated to the household level. Permitting a free range of nonnegative choice for T_W implies a perfect labor market. A logical extension of this work might be to explore specific imperfections. We thank an anonymous reviewer for making this observation.

where λ, μ, ν, φ are the Lagrangian multipliers of the income, time, and fuelwood collection constraints, respectively.

The optimum amounts of fuelwood to collect in VWL and NF are given by

$$\partial L/\partial F_V = \lambda p_F - \nu \leq 0, \quad F_V \geq 0,\ (\partial L/\partial F_V)F_V = 0, \qquad [7]$$

and

$$\partial L/\partial F_N = \lambda p_F - \varphi \leq 0, \quad F_N \geq 0,\ (\partial L/\partial F_N)F_N = 0, \qquad [8]$$

respectively. Fuelwood will be collected from the VWL provided that marginal utility of added income from fuel, λp_F, equals the marginal utility cost of resources required to collect fuel from the VWL, ν. Similarly, fuelwood will be collected from the NF provided that marginal utility of added income from fuel, λp_F, equals the marginal utility cost of resources required to collect fuel from the NF, φ.

Optimum allocations of time for VWL fuel collection, NF fuel collection, wage labor, and leisure are given by

$$\partial L/\partial T_V = -\mu + \nu \partial f_V/\partial T_V \leq 0, \quad T_V \geq 0,\ (\partial L/\partial T_V)T_V = 0, \qquad [9]$$

$$\partial L/\partial T_N = -\mu + \varphi \partial f_N/\partial T_N \leq 0, \quad T_N \geq 0,\ (\partial L/\partial T_N)T_N = 0, \qquad [10]$$

$$\partial L/\partial T_W = \lambda w - \mu \leq 0, \quad T_W \geq 0,\ (\partial L/\partial T_W)T_W = 0, \qquad [11]$$

and

$$\partial L/\partial T_L = \partial u/\partial T_L - \mu \leq 0, \quad T_L \geq 0,\ (\partial L/\partial T_L)T_L = 0, \qquad [12]$$

respectively. Time will be allocated to VWL (NF) fuel collection provided that the marginal utility value of added fuel production, $\nu\partial f_V/\partial T_V$ ($\varphi\partial f_N/\partial T_N$), equals the marginal opportunity cost of time, μ. Similarly, time will be allocated to wage labor provided that the marginal utility of added income, λw, equals the marginal opportunity cost of time, μ. Finally, time will be allocated to leisure until the marginal utility of leisure time, $\partial u/\partial T_L$, equals the marginal opportunity cost of time, μ.

From these conditions, we can summarize when households (1) will collect in both VWL and NF; (2) will not collect in the VWL; (3) will not collect in the NF; and finally, (4) will not collect at all. The discussion can be facilitated by interpreting the multipliers λ, ν, and φ, as the marginal utility of monetary income,[4] shadow price of fuel collected from the VWL, and the shadow price of fuel collected from the NF, respectively. The economic conditions under which collection from the NF is reduced are the focus of our empirical work.

Collection in Both VWL and NF

When households optimally collect from both VWL and NF, the marginal products from collection in VWL and NF would be the same for the households engaged in both activities. For those who have access to a market the collection is ‘‘capped’’ by the price of fuel: $p_F = \nu/\lambda = \varphi/\lambda$.

No Collection in VWL (But Collection in NF and Possibly Market Purchase)

With no optimum collection in VWL, $F_V = 0$, suggesting that $\partial L/\partial F_V < 0$. If $\partial L/\partial F_V < 0$, then the shadow price of VWL collection, ν, exceeds the marginal utility of added income from fuel, λp_F. When this is true the household could be expected to purchase fuel. However, since the shadow prices for the VWL and NF are not necessarily the same, (ν could not in general be expected to equal φ), then the household might still collect in the NF when: $p_F = \nu/\lambda < \varphi/\lambda$.

No Collection in NF (But Collection in VWL and Possibly Market Purchase)

When households do not collect in the NF the optimum is $F_N = 0$. Since $F_N = 0$ implies

[4] A common assumption is that $\lambda = 1$. It gives intuitive interpretations easily tested in empirical analysis, but is definitely a simplification. For an empirical estimation of the marginal utility of money for different income groups in India see e.g., Sharma, McGregor, and Blyth (1991).

that $T_N = 0$, the first order conditions for collection times T_N and T_V (see [9] and [10] above) show that $\nu\partial f_V/\partial T_V > \varphi\partial f_N/\partial T_N$. Under these conditions, collection in VWL brings more utility than collection in NF. Whether this is enough to actually spur collection by a specific household depends on whether the price of fuel is greater than the shadow price of fuel collection/marginal utility of cash income (see above).

No Collection

There is a possibility that there will be no collection at all. The obvious case is when the opportunity cost of time is too high, for example, because of wage labor. Reorganizing the optimum allocations of time to VWL, NF, and wage labor suggests that optimum $T_V = T_N = 0$ when: $w > (\nu\partial f_V/\partial T_V)/\lambda$ and $w > (\varphi\partial f_N/\partial T_N)/\lambda$.

II. EMPIRICAL ANALYSIS OF FUEL COLLECTION FROM NATURAL FORESTS

In each of these cases the decisive marginal returns from collection depend on household characteristics and resource accessibility, A and R_i. These characteristics differ between households and villages, respectively. Köhlin (1998, Chapter 3) found statistically significant differences among VWL and NF collection when households and villages were stratified by caste, gender, and other categories. Our empirical focus is on the determinants of time allocated to NF fuel collection, and how the introduction of VWLs can decrease pressure on natural forests.

From the household model and the discussion of the Kuhn-Tucker conditions we can conclude a reduced form labor supply function for collection in NF.[5] Household time allocated to NF collection, T_N, can be expected to depend on the marginal products (shadow wages) from collection in NF and VWL (to conserve notation, $\partial f_V/\partial T_V$ and $\partial f_N/\partial T_N$ for a household will be written below as f'_V and f'_N), market wages, w, exogenous income, Y, household characteristics, A, and resource availability, R,

$$T_N = t(f'_N, f'_V, w, Y, A, R) \qquad [13]$$

The change in T_N for a particular household can then be estimated using the marginal effect of f'_V on T_N simply:

$$\Delta T_N = (\partial T_N/\partial f'_V)\Delta f'_V. \qquad [14]$$

If we assume that the marginal product f'_N is constant in this interval, then the change in collection in the natural forest, F_N, is

$$\Delta F_N = \Delta T_N f'_N. \qquad [15]$$

Household time spent collecting in the NF and the resulting changes in collection in the NF will both be analyzed using household data collected from villages in Orissa.

Data

The data were collected in Orissa in February 1995. The data set contains 742 household observations based on personal interviews by professional enumerators. The households were visited in 22 randomly selected villages in the vicinity of a common forest, the Dhani Reserve Forest.

The data set features detailed information regarding collection in both VWL and NF with time spent per trip, quantity collected per trip, and number of trips over the last year. In the following analysis the modern fuels have been excluded and the different biomass fuels have been converted to "leaf equivalents" (Köhlin 1998, Chapter 2). The sources of fuel have been aggregated to natural forest (NF) and village woodlot (VWL).

Estimation of Time Spent Collecting Fuel in the Natural Forest

In order to identify the potential decreased pressure on NF we need to estimate an empirical representation of the reduced form time allocation function, $t(f'_{Nh}, f'_{Vh}, w_h, Y_h, A_h, R)$. The analysis is carried out at the household level. Because less than half (279 of 742) of the households collect in the NF, a Heckman specification with sample selection

[5] The authors are indebted to Professor Ramon López for this insight.

TABLE 1

Fuelwood Collection in Natural Forests by Households in 22 Randomly Selected Villages in Orissa, India, 1995

Variable	Mean	Standard Deviation	Range
Probability of collection in natural forest	0.38	0.48	0–1
Time spent collecting in natural forest (hours per year)	484	1,271	3–11620
Age of head of household (years)	50	14	12–90
Family size	5.9	2.7	1–24
Men older than 15 as share of family	0.35	0.17	0–1
Number of schedule caste/tribe women in household	0.29	0.72	0–5
Schedule caste/tribe dummy	0.18	0.38	0–1
High caste (Brahmin/Khandayat) dummy	0.44	0.5	0–1
Total income including agricultural produce (rupees)	15,850	18,300	−400–252,000
Distance to forest (km)	2.75	1.78	0–6
Size of Informal Protection Committee (IPC) area (acres per household)	4	11	0–86
Informal Protection Committee (IPC) age (years of protection)	3.3	5.5	0–15
Size of village forest (acres per household)	0.2	0.4	0–1.8
Size of village woodlot (ha per household)			
Household marginal product in natural forest (kg per hour)	3.9	8.1	0–63
Household marginal product in village woodlot (kg per hour)	3.4	5.8	0–61
Natural forest wage − village woodlot wage (rupees per hour)	−0.2	6.8	−54–61
Natural forest wage − market wage (rupees per hour)	−2.4	8.8	−85–49

is used. In this two-step procedure, the discrete decision of whether to collect in the NF is first analyzed using a probit model, then the continuous decision of time to spend collecting is analyzed using a sample selection procedure.

Descriptive statistics for the variables used are presented in Table 1. The age of the head of household is expected to reduce the probability of collection because old households have less mobility. Family size is expected to be a major determinant of household fuel needs and is therefore expected to increase both probability to collect and the time allocated to collecting. Preliminary analyses indicate that there are two groups in the household that are positively correlated to collection in NF, women in scheduled caste or scheduled tribe (SCST, or low caste) households and men in general. These are included as share of men in the household and an interaction term based on number of women in the household and a dummy for SCST households. Dummies for low and high castes are also included in both steps, with ''general caste'' as the reference point. Income is included and is expected to decrease collection since market purchase and modern fuels become more interesting for households with a high opportunity cost of time and a lower marginal utility of money. The income variable used is a composite of all monetary incomes from wage labor, sale of agricultural products, livestock and other products. To this has been added an estimation of the value of subsistence production by taking the quantity of the staple rice produced times its market value. A final modification is the inclusion of net transfers to and from the household.

A number of resource variables have been included. The size of potential village forest per household is expected to be positively related to the decision to collect. Time spent collecting in village forests are included in the second stage of the estimation. The size of jurisdiction and age of existing informal protection committees (IPCs) for the forest is

TABLE 2
PROBIT ANALYSIS OF HOUSEHOLDS' DECISION TO COLLECT IN NATURAL FOREST, ORISSA, INDIA, 1995

Variable	Marginal Effect	t-Value
Constant	−0.29***	−3.26
Age of head of household	−0.002	−1.10
Family size	0.02**	2.10
Share of men in household	0.18	1.42
Number of SCST women in household	0.15***	2.62
Low caste	0.07	0.60
High caste	0.08*	1.70
Total income (10^{-6})	−0.85	−0.60
IPC area per household	−0.006**	−2.10
Age of IPC	0.014***	2.53
Village forest area per household	0.07	1.52
NF wage − VWL wage	0.027***	6.38
NF wage − market wage	0.01***	4.31

* indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

also included. A village forest is a (remnant of a) natural forest close by the village. Not all villages have such nearby forest areas and their utilization is probably informally restricted.

IPCs are organized to better manage natural forest areas. They typically imply both restriction of the forest area to "outsiders" and regulate the use of the forest to the eligible villagers. This is why it is expected to affect forest utilization over and above its impact on marginal product. It has been shown that IPCs in the area have improved the quality of the forest. The results in Table 2 imply that as time goes by the restrictions on the members decrease which enables them to spend more time collecting in the natural forest.

Finally, two variables emanate from the household's optimum decisions. The decision to collect should depend on the relative prices of different sources of fuel, such as NF, VWL, and the market. The relevant prices are the opportunity costs of time. We have therefore included the difference between the shadow wages for fuel from NF and VWL [NF wage − VWL wage] as well as the difference between the shadow wages for fuel from NF and wage labor [NF wage − market wage]. The shadow wages are calculated using the marginal products[6] multiplied by the local market price for fuel. The market wage is based on reported wages and labor days. All wages are expressed in rupees per hour.

In the second step of our Heckman specification, the dependent variable is the natural logarithm of the household time spent collecting in the NF. Explanatory variables include marginal products from collection in NF and VWL, as well as selected household characteristics.

Endogeneity stems from the fact that the time allocation decision and the marginal product for collection in NF are not independent. Because the marginal product for collection in NF is endogenous, the model is estimated using an instrumental variable for f'_N. The probit equation is estimated first, then f'_N is regressed on a number of instruments[7]. The fitted values are kept for use in the second step estimation. The original variable is used when computing the estimate of the disturbance variance (Greene 1995).

The results from the probit step are presented in Table 2. Significant variables have the expected signs. Worth noting is the significance of household variables such as age of head of household and number of SCST women in the household. This is an empirical

[6] Six separate collection functions were estimated for men's collection in NF, women's collection in NF, men's collection in VWL, women's collection in VWL, boys (5–15) collection in VWL and, finally, girls (5–15) collection in VWL (Köhlin 1998, Chapter 2). The estimation used a sample selection procedure and maximum likelihood estimator. The estimations enabled us to calculate the marginal product of collection in the natural forest and in village woodlots by multiplying labor input elasticities, by the ratio of predicted quantity produced to time spent (Mekonnen 1998; Jacoby 1993; Skoufias 1994). Here we use the marginal products aggregated to the household level in the form of weighted averages for collection in NF and VWL separately.

[7] The instruments used were number of women, family size, sex of head of household, average education of family, total income, two caste dummies, distance to forest, size of VWL, village forest and IPC per household, a vegetation index for a radius of 1.5 km for each village from the GIS, use of cart, sale of collected fuels, and if the village has electricity. The adjusted R^2 for the equation was 0.73.

TABLE 3
THE DETERMINANTS OF HOUSEHOLD TIME FOR COLLECTION IN NATURAL FORESTS, ORISSA, INDIA, 1995

Variable	Coefficient	t-Value	Marginal Effect	t-Value
Constant	4.35***	8.08		
Marginal product in village woodlot	−0.052***	−3.40		
Marginal product in natural forest	−0.031**	−2.27		
Family size	0.09***	3.16	0.054*	1.76
Number of SCST women	0.35**	2.10	0.62	0.32
Low caste	1.00***	2.69	0.85**	2.08
High caste	0.12	0.66	−0.02	−0.10
Village forest area per household	0.80***	4.63	0.67***	3.58
Inverse Mill's Ratio	1.10***	2.94		

Note: The results are from the second step of Heckman two-stage estimation.
* indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

reminder to be cautious of uniform approaches to extension community forestry programs: Different households have very diverse strategies to meet their basic needs.

The relative wage measures have very strong explanatory power. The marginal effects indicate that collection in VWL have greater leverage than wage labor. This could be due to the fact that it is a closer substitute in household labor allocation. An indication of the size of the effect of VWL on the probability of collection in NF can be obtained by multiplying the marginal effect, at sample mean, of the "NF wage − VWL wage" variable (0.027) by the mean of the VWLwage variable for those who collect in VWL (7.15). On average the establishment of the VWL has changed the "NF wage − VWL wage" variable by −7.15. This implies a reduced probability of 19% for collection in NF for those who collect in the VWL (−7.15 times 0.027).

Results from the model of time allocated to collection in natural forests are given in Table 3. The variables suggested by the model have overall high significance. The marginal product in VWL, f'_V, is negative and significant, suggesting that the higher the marginal product in VWL, the less time is allocated for collection in NF. The negative sign of the marginal product in NF f'_N, implies that when accessibility of fuel decreases, households spend more time collecting in the NF. If fuel becomes more accessible in NF, then households take out at least part of this improvement in terms of reduced collection time.[8]

The coefficients for family size, low caste households, and low caste women have the expected positive and significant signs, while high caste households are not significantly different from the reference group. Finally, the significant Inverse Mill's Ratio reminds us that these results are conditional on the collection decision.

Table 4 builds on these results, and quantifies the impact of village woodlots on collection times and amounts in natural forests. First, the reduction in household time allocated to collection in NF is calculated using the marginal effect of f'_V on T_N and the actual f'_V for collecting households as proposed in equation [14]. Village averages for households (N) affected by this time effect are presented as "*Decreased Time in NF*." This is the reduction in time devoted to collection in NF per household and year due to the availability of VWL. It is reasonable to expect, as suggested in equation [15], that the affected households would have collected in the NF roughly at their marginal productivity also in this time interval. That would result in a quantity reported in Table 4 as "*Decreased Collection in NF*" (kg/hh/yr). If we expect

[8] The negative coefficient on marginal product in the natural forest may be due in part to measurement error, to the extent that this explanatory variable is a function of the dependent variable. The authors thank an anonymous reviewer for making this observation.

TABLE 4
CHANGES IN COLLECTION IN NATURAL FOREST (NF) DUE TO VILLAGE WOODLOT (VWL), ORISSA, INDIA, 1995

Village Name	Decreased Time in NF (hours/ household/ year)	Decreased Collection in NF (kg/household/ year)	Decreased Village Collection in NF (kg/year)	Percent Decrease in Collection in NF
Champapedi	140	870	38,800	29
Krushnapur	160	840	29,200	14
Khandisi	100	600	11,500	4
Kerendatangi	60	540	32,000	21
Nakithana	190	1,040	17,000	6
Arjunpur	440	1,580	42,700	23
Kiapalla	0	0	0	0
Raipada	310	1,490	41,800	5
Kadamjhola	170	900	9,900	4
Mayurjhelia	220	780	17,600	18
Hariharpur	70	410	3,400	11
Narasinghpur	380	860	76,300	17
Patharbandha	90	760	5,600	24
Tangi	0	0	0	0
Balarampur	170	1,140	15,900	13
Chandapur	120	430	28,800	18
Average	170	790	21,400	13

our sample to be representative for the rest of the village we can aggregate the reduced pressure to the village level, shown as *"Decreased Village Collection in NF."* Because the estimates presented in Table 4 are functions of other parameters which are estimated with some error (Tables 2 and 3), they should be interpreted as rough estimates.

The variation in impact is large between villages (as expected). This method underestimates the impact, because it does not take into account the decreased pressure resulting from households abstaining completely from collection in NF due to VWL. This is especially evident in the case of Tangi, where no one in the sample collected in the forest. Still, substantial reductions in collection in NF are found. From these villages alone, pressure on nearby forests such as Dhani Reserve Forest is decreased by roughly 340 metric tons of biomass per year. This amount constitutes about 13% of current collection. The estimated decreased collection can also be compared with actual collection in VWL, which is reported to be twice as large. This defies any simplistic notion of a one-to-one relationship between collection in VWL and reduced collection in NF.

III. SPATIAL VARIATION OF FUELWOOD COLLECTION IN NATURAL FORESTS

In the preceding analysis we have shown how the collection decision depends on the relative returns from different sources of fuel. We have also indicated that distance to the forest is a crucial factor behind this. Because shadow wages are difficult to estimate, we will reexamine the decision to collect in NF, focusing on underlying factors that can be of interest for policies regarding forest intervention. For example, distance to NF could be expected to affect the shadow wage and thus behavior. If VWL at different distances to the NF have different impacts on collection, this will have implications for optimum locations of VWL. We therefore introduce an interaction term between the availability of VWL, expressed as hectares of VWL per household, and the distance to NF. Since we cannot expect this relationship to

TABLE 5

PROBIT ANALYSIS OF HOUSEHOLDS' DECISION TO COLLECT IN NATURAL FOREST, ORISSA, INDIA, 1995, WITH SPECIAL FOCUS ON SPATIAL VARIATION

Variable	Marginal Effect	*t*-Value
Constant	0.21**	2.00
Age of head of household	−0.004**	−2.20
Family size	0.02***	2.53
Share of men in household	0.26	2.04
Number of SCST women in household	0.19***	3.12
Low caste	0.06	0.54
High caste	0.07	1.56
Total income (10^{-5})	−0.34***	−2.47
IPC area per household	−0.004	−1.46
Age of IPC	0.007	1.07
Village forest area per household	−0.03	−0.49
Distance to NF	−0.13***	−7.98
Size of VWL per household times distance to NF	−0.73***	−3.86
Size of VWL per household times distance to NF squared	0.13***	3.26

* indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

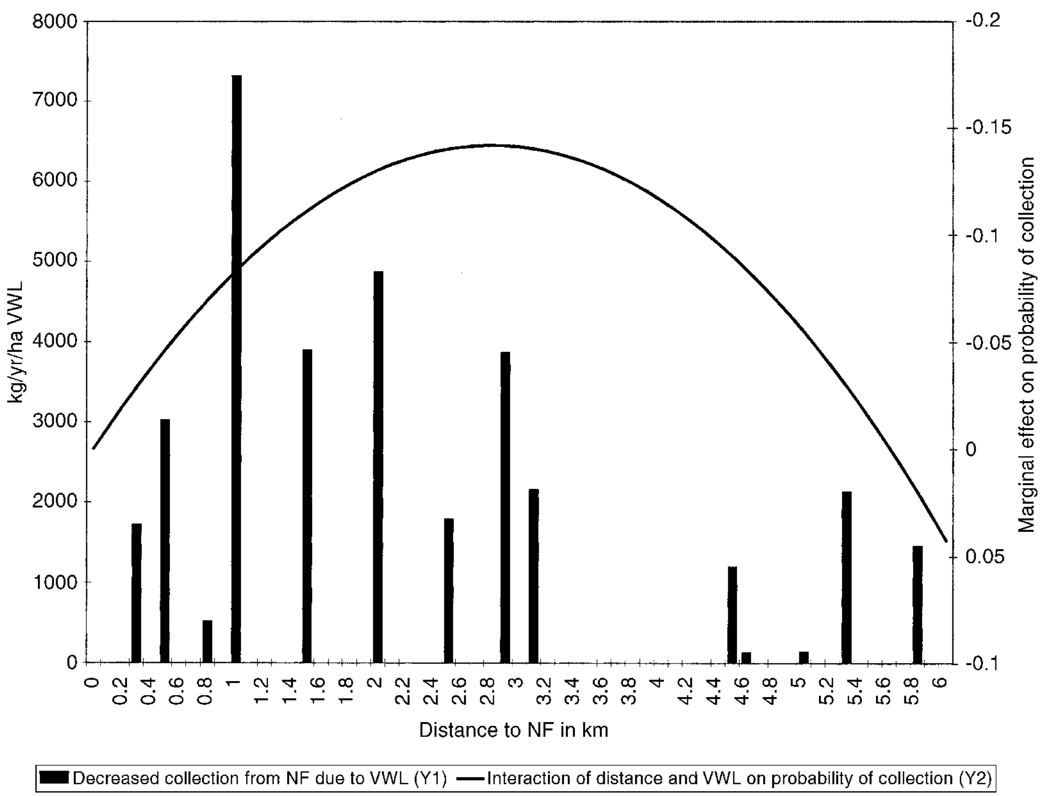

FIGURE 1

REDUCTION IN COLLECTION IN NATURAL FOREST (NF) DUE TO VILLAGE WOODLOT (VWL) AS A FUNCTION OF DISTANCE be linear, different specifications were tested and the quadratic form performed by far the best.[9]

The results of this alternative probit specification can be found in Table 5. Since the shadow wages are excluded, the underlying household characteristics become even more pronounced. We can also note that our spatial variables, distance and interaction terms between distance and VWL, are all significant at the one percent level.

Figure 1 is based on both the estimated reduction in collection in NF (Table 4) and the estimated change in collection in NF due to interaction between availability of VWL and distance to the natural forest. The curve in Figure 1 is an extrapolation within the range of our observations of marginal effects, calculated at the mean distance of 2.8 km. The figure shows that the decrease in probability reaches a maximum at around this mean distance from the natural forest. The trend is quadratic in both cases, and shows an inverted U shape. This trend implies that to decrease the collection in natural forests using community plantations, these plantations should not be located near villages that are very close or very far from the natural forest. In the first case, the natural forest will almost always be a superior source of biomass, and in the latter case, the forest is so inaccessible that other sources are chosen in any case.

The fact that plantations have the potential to reduce deforestation is important. It is also important that the degree of success depends on location. Location-specific effects help to explain the variable success of plantations. These results motivate against summarily rejecting all plantations as a means to reduce fuelwood collection in natural forests. Although poorly located plantations may have little effect, appropriately located plantations appear to offer considerable promise as a means to accomplish reduced deforestation in natural forests.

IV. DISCUSSION

Reduced deforestation is a common reason for investment in social forestry projects. In that tradition earlier evaluations of the Orissa Social Forestry Project (e.g., SIDA 1992) have postulated that the major environmental benefit from the project would be decreased pressure on natural forest as the result of the establishment of 100,000 ha of community plantations.

No empirical evidence has been given to support this contention. On the contrary, some forest officers in Orissa even argued that the secure user rights of the VWL would even increase the pressure on the de facto open access forest resources. We have shown that in the villages around Dhani Reserved Forest, establishment of VWL has both decreased the probability for collection in NF and the pressure on the forest among those who collect.

At this point it would have been nice to be able to compare the environmental benefits from plantations at different locations with the costs to establish them in a way that could guide future forestry interventions. However, an estimation of the welfare effect of the decreased pressure is beyond the scope of this paper. Even if it had been possible to carry out such a social cost benefit analysis it would not necessarily have guaranteed successful implementation, since that rests heavily on the incentives and resulting commitment of the surrounding people. In order to test whether there was such a commitment a contingent valuation study was carried out. In many of the villages people revealed a substantial willingness to pay for a new plantation, high enough to pass a net present value test (Köhlin 2001).

One reason for this could be the fact that the plantations reduce the pressure on the natural forest and that households are already heavily involved in collection of nontimber forest products. With reduced pressure on the forest these incomes can be expected to grow, as will the sale of valuable species such as bamboo, sal, and teak. Johansson (1996) made a separate study that focused on the value of protection of NF in five of the villages in our sample, Kiapalla, Barapalli, Ardjunpur, Balarampur, and Panaspur. She found that after eight years of protection the villages received gross returns of half a mil-

[9] Different specifications for distance were also tested.

lion rupees worth of nontimber forest products yearly, when valued at market price of closest substitute. The commercial timber species were expected to give the returns of the same order of magnitude to the villages, despite a 50-50 sharing arrangement with the Forest Department.

It is easy to make conjectures between the availability of alternative sources of fuel such as VWL and protection of the natural forest. A relevant question is whether the villagers themselves see this connection. One third of the households that have access to VWL felt it improved the possibility of protecting the natural forest. The major reason stated for this, however, was not the increased availability of biomass, but rather that the management of the VWL had shown the way to collective action.

V. IMPLICATIONS FOR PROJECT PLANNING

The most important result of this research is that plantations can be used to decrease the pressure on forests. This could imply that the criticized strategies to subsidize plantations might have been more successful than expected. This is particularly true if there are not enough local benefits for plantations to emerge spontaneously by collective action and if there are significant positive externalities emanating from the forest.

A finer detail is that we have found that plantations close to the forest are used less than plantations located further away. The impact of VWL on the pressure on natural forests therefore seems to be best described by the inverted U-shape of Figure 1. This finding has important implications regarding the ubiquitous recommendation to establish buffer zones around areas worthy of protection. The reason for this is that "buffer zones have become so popular, in fact, that they are part of virtually all proposals for protecting natural areas" (Wells and Brandon 1992, 25). This is to a large extent due to their intuitive appeal and the combined biological and social benefits that they "promise" (Poore and Sayer 1987).

Buffer zones of this type have been integral parts of social forestry projects, such as the "interface forestry" component of the SIDA-supported project in Tamil Nadu (Eggert and Carlsson 1995). Actual success in achieving the expected benefits has been less than forthcoming. These experiences led Wells and Brandon to sum up: "current buffer zone definitions are inconsistent and overlook practical problems, and this precludes their implementation in all but very limited circumstances. The buffer zone concept, although deceptively simple and intuitively very appealing, thus faces considerable challenges. It remains, however, a high priority for many conservation programs" (Wells and Brandon 1992, 27).

Our analysis of the spatial variation in how plantations affect the pressure on natural forests is one piece of evidence that could make conservation programs more efficient in the future. If we combine this with the incidence of other potential benefits of plantations such as reduced time for collection and expenses for purchase of fuel, then, as a rule of thumb, village woodlots seem to be more beneficial further away from the natural forest, where biomass is scarce and market purchases of fuel are common.

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