Analyzing the Impact of Excluding Rural People from Protected Forests: Spatial Resource Degradation and Rural Welfare

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Abstract

This paper examines how forest-dependent villagers meet a resource requirement when they are excluded from some area of a forest. Forest managers who value both pristine and degraded forest should take into account a "displacement effect" resulting in more intensive villager extraction elsewhere, and a "replacement effect" in which villagers purchase more of the resource from the market. Similarly, forest managers who have poverty concerns should recognize that exclusion zones tend to be more costly to villagers without market access and those with low opportunity costs of labour – typically the poorest villagers.

1. Introduction

Exclusion of local populations from specific protected areas is a common, if contentious, practice in less-developed countries (Wells and Brandon, 1992; Wells, 2003). Such exclusion may be considered necessary to protect vulnerable forested areas from degradation that reduces the flow and stock of environmental services, including timber and biodiversity conservation. Yet excluding villagers from one part of a forest may simply displace extraction activities into a smaller area, or into another nearby forest, thus increasing degradation there. Many conservationists suggest that encouraging conservation outside of strictly protected areas is as necessary to the provision of environmental services as the protected areas themselves, which implies that the impact of this displacement matters (Vandergeest, 1999; Faith 1996). Moreover, forest and park departments have come under pressure in recent years to address the impact of their policies on resource dependent villagers in and around the forests (White and Martin, 2002; Wells, 2003). This paper addresses both changes in rural welfare and forest resource densities when people are excluded from some specific area of a forest but remain dependent on its resources, such as fuelwood.

This paper has some similarities with de Meza and Gould (1992, p. 579), in which activities that are excluded from one area lead to "congestion … on sites to which access is still free." In the literature on forest extraction, issues of such displacement of activities have been mentioned but rarely modelled (Pattanayak, et al. 2004; Kohlin and Parks, 2001). However, this paper explicitly models the spatial patterns of exclusion and displacement of extraction, and introduces the extra dimension of how intensively villagers harvest the resource. Because villagers' decisions about extraction contain both an intensity and a location dimension, villager response to different sized exclusion areas creates different spatial patterns of resource density across the forest. If, as Lewis (2002, p.9) states, "concentrating previously dispersed … activities into certain parts of the forest may actually increase the negative ecological impact … by concentrating it in limited areas," then the level of environmental services provided by the forest as a whole can be negatively effected by the displacement of extraction from the protected area.

From the forest manager's perspective, the benefits of exclusion, in addition to protecting a pristine area of forest, depend on the value attached to non-pristine areas beyond the protected area. This paper shows that governments could engage in excessive exclusion if they do not take into account the likely result of increased degradation outside the protected area. At one extreme, if only pristine resources are valued by the planner, the impact of exclusion elsewhere is irrelevant from the perspective of the resource manager. But, if any value is attached to non-pristine resources outside of the protected area, then this "displacement effect" cannot be ignored.

The paper also emphasizes the role of markets in determining the pattern of resource densities and rural welfare. If villagers can buy the resource in a market, the market creates a "replacement effect" in which the exclusion zone induces villagers to replace a portion (or all) of their extraction with purchases from the market. The degree to which villagers interact with markets, and the costs of interacting with markets, contributes to the amount of displaced extraction and therefore to the pattern of resource densities.

Local populations are made worse off by exclusion policies because they incur higher costs to procure the resource (Shyamsundar and Kramer, 1996). These people therefore bear a potentially large cost when excluded from a protected area and that cost may not be offset by locally-accruing conservation benefits. This paper demonstrates why it should be expected that the poorest households are made worse off than less poor households by exclusion policies, through analysis of the displacement and replacement effects. If marketing transactions costs are low, villagers, particularly those with high opportunity costs of time, are more likely to rely on the market rather than intensify their extraction effort within the remaining extraction zone. In contrast, if marketing costs are high, villagers, particularly those with low opportunity costs of time and inflexible consumption needs, will extract more intensively from the smaller extraction zone resulting in higher levels of resource degradation there. It is these villagers for whom a policy of exclusion is likely to have the greatest negative welfare effect.

This paper develops a model of villager extraction decisions and labour allocation that incorporates costs of intensity, location/distance, and market access, which appear to be important empirically (Pattanayak, et al. 2004; Kohlin and Parks, 2001). Using simulation analysis, the results depict the spatial patterns of resource densities and the differential welfare impact across villager types in response to policies that exclude people from extracting in different sized protected areas.

2. The model

Consider a number of villagers adjacent to a forest over which a forest manager has responsibility. The forest manager prevents villagers from entering and extracting from some specific area of the forest, relying on boundary enforcement such as patrols, fines, and fences to exclude the villagers. Enforcement levels are sufficient such that the villagers choose to turn around at or before this protected area boundary, which is a distance X_B from the village, rather than risk being caught and punished within the protected area.[1]

A representative villager maximizes net revenues from extraction, subject to a consumption requirement *R* and the forest manager's exclusion policy, which imposes a maximum distance X_B that the villager can go into the forest to extract.[2] *H* is the total volume of resource harvested, or extracted. *C* represents the time cost of extraction. Any surplus *S* that is extracted can be sold to the market at a price *p* but

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1 To suggest full compliance may at first seem unlikely, especially given the expansive literature on optimal enforcement that stresses that full exclusion is the exception rather than the rule (Becker, 1968; Stigler, 1970; Shavell, 1993). However, complete exclusion from one particular area of forest combined with displacement into the surrounding areas is in fact an example of the consequence of marginal deterrence. Deterrence, whether a physical barrier such as a fence, or patrols and the threat of a fine, can be designed such that villagers choose to undertake the less-harmful and less costly activity of purchasing from a nearby market or extraction in the periphery – closer to home and no fines – rather than the more harmful and more costly activity of extraction in the protected area – further from home and with the possibility of fines (Friedman and Sjostrom, 1993; Mookherjee and Png, 1994).

2 For simplicity in this paper, each household consumes some essential level of the resource (whether they buy it or extract it) to meet a base energy consumption requirement. For example, a household may require a set level of fuelwood each day to be used for cooking and heating, and additional fuelwood affords no further benefits other than as a marketable good where an accessible market exists. This simplifying assumption is supported by empirical analysis including Pattanayak, et al. (2004)'s evidence that fuelwood demand is highly inelastic and is an essential good.

incurs transportation costs of *y*. Similarly, any deficit *D* can be purchased from the market, but again transportation costs of *y* are incurred. In sum, the villager contemplates the following single–period optimisation of total returns V :

$$\max_{w,X_D}[V] = \max_{w,X_D}\{(p-y)S-(p+y)D-C\}$$

$$\text{s.t. } D-S=R-H\text{ ; } H,S,D\geq 0\text{ ; } SD=0\text{.} \qquad [1]$$

To solve the model explicitly, functional forms for the harvest and cost functions are chosen that are simple enough to permit analytical solutions while maintaining the required characteristics in terms of first and second–order derivatives (general forms of the equations can be found in Robinson et al, 2002).

Harvest intensity at a distance *x* from the village is written:

$$h(x) = m(x)\left(1-\frac{1}{(1+\beta(w(x)-v))}\right) \text{ where } \beta = \alpha\frac{m(x)}{M} \qquad [2]$$

In Equation 2, *v* is the time it takes to traverse a unit distance when not extracting, $w(x)$ is the actual time taken by the villager per unit distance travelled while extracting (the inverse of her speed), $m(x)$ is the resource density per unit distance at the start of the period and *M* is the maximum resource density. α represents the effectiveness of the villager's extraction effort. Assume *m* is constant over distance before any extraction has occurred, hence $w(x)$ is not a function of distance and can simply be written *w*.

The total amount harvested H is written hX_D, where X_D is the furthest distance the villager goes into the forest:

$$H = m\left(1 - \frac{1}{\left(1 + \beta\left(w - v\right)\right)}\right)X_D \text{ where } \beta = \alpha\frac{m}{M} \text{ and } X_D \leq X_B \qquad [3]$$

The cost of extraction, C, for an individual villager with opportunity cost of labour *k* is a function of the total time, wX_D, the villager spends in the forest:

$$C = k\left(\frac{1}{\gamma}\left(wX_D + 1\right)^{\gamma} - \frac{1}{\gamma}\right) \qquad [4]$$

$\gamma > 1$, implying an increasing opportunity cost of time over time.

This model is in keeping with other household resource extraction models in its use of scarce labour time as the primary input to producing the extracted forest product (Pattanayak, et al. 2004; Kohlin and Parks, 2001; Amacher, Hyde, and Kanel, 1996; Bluffstone, 1995). Many of these papers also model extraction as a function of the resource's quality or availability, as in this paper (Pattanayak, et al. 2004; Kohlin and Parks, 2001). In addition, the model's use of transactions costs to depict a degree of market access echoes that style of analysis in the agricultural literature (Key, Sadoulet, and de Janvry, 2000; Omamo, 1998). This paper expands the extraction production function to more fully explore the issues of how extraction intensity and location decisions interact with the opportunity cost of labour time and the access to markets.

The representative villager's optimal pattern of extraction depends on her "type" which in turn depends on the market conditions and the extent of exclusion. She can be a "subsistence" villager, extracting exactly the requirement *R*. She can be a "supplementing" villager, purchasing at least some of her requirement from the market. Or she can be "selling" villager, selling an excess over and above the consumption requirement to the market. (A fourth type, “non-extractors,” is a subset of supplementing villagers, where each villager purchases their full requirement from the market.)

The model is solved assuming that the villager’s “natural core”—the distance she travels when unconstrained by exclusion or enforcement activities—lies within the exclusion zone; that is, that the exclusion zone is a binding constraint on her activities and so $X_D = X_B$ and her only choice variable is *w*. The equivalent equations for the unconstrained villager, as derived in Robinson et al (2002), are reproduced in Appendix 1 for completeness.

If the villager is a subsistence villager after the exclusion zone is in place, from Equations 1 and 3:

$$H = R = m\left(1 - \left(1 + \alpha\, m/M\,(w - v)\right)^{-1}\right)X_B$$

Hence:

$$w - v = \frac{R}{\beta(mX_B - R)} \qquad [5]$$

Intuitively, because a subsistence villager gets her full requirement *R* from the forest, constraining her extraction activities into a smaller area increases the harvest intensity in that smaller extraction zone but does not affect the market.

If, when the exclusion zone is in place, she is a supplementing villager who both extracts and purchases, and if her natural core is in the exclusion zone, *S=0* and

$D = R - H$. Because the villager is constrained by the exclusion zone, $X_D = X_B$.

Equation 3 is rewritten:

$$H(X_B) = m\left(1 - \frac{1}{(1+\beta(w-v))}\right)X_B$$

and Equation 1 is rewritten:

$$\max_w\left\{-(p+y)\left(R - m\left(1 - \frac{1}{1+\beta(w-v)}\right)X_B\right) - k\left(\frac{1}{\gamma}(wX_B+1)^{\gamma} - \frac{1}{\gamma}\right)\right\}$$

Differentiating with respect to w results in the first–order condition governing the optimal choice for w:

$$(p+y)m\beta = k(wX_B+1)^{\gamma-1}(1+\beta(w-v))^2 \qquad [6]$$

From Equation 6 it can be seen that for the supplementing villager constrained by the exclusion zone, w is a function of both opportunity cost of time, k , and the location of the exclusion zone's boundary, X_B . In comparison, where villagers are unconstrained, extraction intensity is not a function of k (Appendix 1).

Similarly, if the representative villager both extracts and sells a surplus when the exclusion zone is in place, the equilibrium condition that governs w is:

$$(p-y)m\beta = k(wX_B+1)^{\gamma-1}(1+\beta(w-v))^2 \qquad [7]$$

These conditions hold for the relevant type of villager—subsistence, supplementing, or selling—when the exclusion zone is in place. But the act of excluding villagers from part of the forest can alter the villager's type. For example, a subsistence villager who initially extracts exactly the amount required for her own consumption when unconstrained may, when confronted by the exclusion area, either continue to extract the exact requirement *R,* or may extract less than *R* and start to use the market, thereby becoming a supplementing villager. Whether or not she uses the market depends on the size of the marketing costs *y* and the extent of the exclusion. The smaller the marketing costs and the greater the exclusion zone, the more likely that she will become a supplementing villager.

To determine the villager's type after the exclusion zone has been put in place, her endogenously determined extraction intensity *w* is substituted into Equation 3 to determine the total amount extracted. If $H < R$, then the she is a supplementing villager who both purchases and extracts; if $H > R$ then she is a selling villager; if $H = R$, then she is a subsistence villager.

3. Simulation Analysis

To explore the relationships between exclusion and extraction patterns, the model is calibrated and solved explicitly. The calibration parameters are chosen to illustrate the key points of the model.[3] The villager's type is defined by her unconstrained type, thereby allowing investigation of the impact of villagers switching type as a result of the policy.

Figure 1 shows how a villager's dependence on the forest and market, and her harvest intensity, are affected by the size of the exclusion zone. For the initially

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[3] For each of the figures, m=3, M=10, α=0.8, v=2, γ=1.2, p=7, R=8. The distance from the village to the furthest point in the forest is set at 8 units, such that the natural core of each villager is within the forest.

subsistence villager, when the exclusion zone is sufficiently small (<1.5 units wide) it is non-binding and so does not affect her extraction behaviour (Figure 1a). When the exclusion zone is small and binding (between 1.5 and 3.35) she intensifies her extraction but continues to extract her full requirement from the now reduced distance available to her. When exclusion is sufficiently large (>3.35) the villager extracts more intensively in the smaller extraction zone but also purchases from the market to supplement her forest extraction. That is, she becomes a supplementing villager. When the exclusion zone takes up the whole of the forest, that is, when it is 8 units wide, the villager can no longer enter the forest and so must purchase the full requirement *R*. Similar graphs are shown for the villager who is initially supplementing or selling (Figures 1b and 1c).

3.1 Differential impact of exclusion on villager welfare

Not surprisingly, from the villager's perspective, when she is excluded from some inner area of the forest, her welfare decreases. The cost per unit of resource extracted increases because she extracts more intensively from the extraction zone, and she may increase the amount she purchases from, or reduce the amount she sells to, the market. Figure 2a shows the total costs of meeting the requirement *R*, comprising time costs of extraction and the cost of purchasing any shortfall from the market, net of any proceeds from selling to the market where applicable, depending on whether the villager is initially supplementing, subsistence, or selling, as a function of the size of the exclusion zone.

Although the total cost is greatest for a villager with a higher opportunity cost of time, for small exclusion zones the implicit penalty imposed on villagers by an exclusion zone is greatest for those with medium opportunity costs of labour, and when the exclusion zone is large the implicit penalty is greatest for those with the lowest opportunity costs of labour – typically the poorest villagers (Figure 2b). Villagers with the lowest opportunity costs of labour have their “natural cores” furthest in the protected area, reflecting their greater dependence on forest resources. Because they travel so far into the forest, poorer villagers are more likely to be affected by an exclusion zone than villagers with higher opportunity costs of labour. The poorer villagers, therefore, bear most of the costs of exclusion. First, they are affected even when the exclusion area is small. Second, the costs of exclusion climb more rapidly for poorer villagers than for richer as the exclusion zone gets larger.

3.2 Exclusion and the forest manager’s objective function

From the forest manager’s perspective exclusion has two effects. Firstly, the pristine area is increased. Secondly, degradation in the extraction zone increases. Hence if the forest manager places any value on the non-pristine extraction zone, he faces a trade off, the extent of which, and hence the optimal level of exclusion, depends on his objective function.

Figure 3 shows the impact of exclusion on degradation – simply the harvest intensity – within the extraction zone.[4] Not surprisingly, the greater the exclusion zone, that is, the smaller the extraction zone, the more intensively villagers extract and the greater the degradation within the extraction zone. However, if villagers supplement from the market, an incremental increase in the size of the exclusion zone

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[4] Because intensity is not a function of distance, degradation is constant throughout the extraction zone for any given size of exclusion zone.

has a smaller impact on degradation than if villagers are, and remain, subsistence villagers. The discontinuities in the slope of the graph for the initially subsistence villager occur when the exclusion zone becomes a binding constraint, and when the exclusion zone is just large enough that the villager begins to interact with the market, and are due to the non-zero transactions costs y.

From the perspective of the forest manager, the optimal level of exclusion will depend on, *inter alia*, his objective function and the cost of enforcement. This paper focuses on the value to the forest manager of the total forest – exclusion zone and extraction zone – as a function of the size of the exclusion zone.[5] Four "preference functions" for the forest manager are considered, and are illustrated graphically in Figure 4, in which "quality" is equal to m-h, and "value" is one if m=3 and zero if m=0. In Figure 4a, the forest manager—who, for example, might be concerned only with biodiversity conservation—values only pristine forest, which implies that the total value of the forest is directly proportional to the width of the exclusion zone. In Figure 4b, the forest manager—who, for example, might be concerned with carbon sequestration—values the sheer quantity of resource rather than the quality of that resource, which implies that the value is directly proportional to the total volume of resource within both exclusion and extraction zones. In Figure 4c, the forest manager—who, for example, might be concerned with biodiversity conservation in addition to a range of ecosystem services—values degraded forest disproportionately less than pristine forest but does not disregard its value. In Figure 4d, the forest manager—who, cares about a range of ecosystem services and values pristine and degraded forest—uses a valuation of biomass function that follows a logistic function, which implies that small incursions by villagers have little impact on the value of the forest, but at some critical level of degradation the forest rapidly loses its value. The provision of many ecosystem services contains this kind of threshold effect. For example, hydrological benefits from watershed forest conservation appear insensitive to small levels of forest degradation but beyond some point the degraded forest contributes little to water flow control (Wu and Boggess, 1999). Similarly, many species thrive in pristine to mildly degraded forests but become locally extinct at some critical point of habitat degradation (Smith, et al. 1998).

Figure 5 illustrates that for functions “a” and “b”, not surprisingly, the greater the exclusion zone size, the greater the value of the whole forest (exclusion and extraction zones) to the forest manager. When the forest manager values only the pristine forest, “a”, naturally the overall value of the forest is lower than for the alternative objective functions “b” through “d”. If the forest manager also values to some extent the degraded forest, as in scenario “b”, then the marginal benefits of exclusion, relative to scenario “a” are lower, as exclusion increases the value of pristine forest but decreases the value of the forest in the extraction zone where extraction is now more intensive.

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[5] This paper does not explore the economics of exclusion from the perspective of the forest manager, rather it focuses on the long–run equilibrium impact of exclusion on villagers’ extraction activities and degradation in the periphery of a forest.

The results for functions “c” and “d” are perhaps the most interesting. In these two cases, the value for the forest is lowest for intermediate sizes of the exclusion zone, this dip in value being most pronounced for scenario “d”. This finding suggests that the choice of exclusion zone size, even without taking into account the enforcement costs of exclusion, requires careful balancing. Both small and large exclusion zones provide higher value to the forest manager than medium sized. This occurs because the intensity of extraction in the extraction zone with the medium sized exclusion zone increases degradation beyond a critical point, and this increased degradation is not fully compensated in the value function by the increased pristine area. But, given the particular shape of the value function, a large exclusion zone provides sufficient benefits from the pristine forest that outweigh the low levels of ecosystem services from the degraded extraction zone. Although this analysis considers only the value to the forest manager and does not explore the costs of exclusion, the results demonstrate that, depending on the specific value function, the forest manager may have to be careful with respect to the critical level of degradation when they pick the size of the exclusion zone.

4. Discussion

Excluding rural resource-dependent people from forests displaces some activities into other forested areas that have less effectively enforced exclusion rules and replaces some extraction with market purchases. The extent of the displacement effect into other forest areas and the replacement effect into the market depends on the villager’s opportunity cost of labour, the villager’s extraction production function, and the cost of participating in the market. Only in the extreme case of a fixed resource requirement and no market access (or sufficiently high marketing costs) is all of the extraction displaced to the extraction zone, whatever its size. Hence, local forest policy that does not take displacement and replacement effects into consideration can lead to socially inefficient levels of exclusion.

This analysis might also inform decisions about which situations could make the best use of woodlots or enrichment of remaining forests and non-forest village land with locally valuable species. For example, where market access costs are high and/or opportunity costs of labour are low, woodlots and planting could prove particularly useful in offsetting the resource degradation caused by increased intensity of extraction in the post-exclusion extraction zone.

If villagers replace some extraction with a substitute from the market, such as kerosene to replace fuelwood, then dependence on the forest resource unambiguously declines. But, if they purchase the same product from the market, questions must be raised concerning the source of the marketed product, particularly if this replacement reflects displacement of extraction to other forests that also provide the marketed resource.

The displacement modelled in this paper contains several simplifying characteristics. First, the model assumes a resource requirement, biasing the results toward more degradation, though not altering the results in a qualitative manner. Second, the market price is assumed to be exogenous, thereby assuming that the market is integrated with more distant markets, rather than being a local market whose price is endogenous to the amount of resource extracted and demanded locally. If market transactions are high relative to the opportunity cost of labour and land, an internal market may develop for which the resource market price will be endogenous to the size of the exclusion zone. Alternatively, villagers may choose to grow the resource on private or common land rather than extract it from the forest.

Exclusion from an area that villagers have used for forest product extraction will decrease the welfare of the villagers even if the villagers can harvest the resource elsewhere in the forest or can purchase it from a market. In this paper the resource requirement enables the welfare implications of the exclusion to be seen in the additional costs of extracting more intensely in the remaining extraction zone and the costs of interacting with the market. Remotely located villagers, for whom market transactions costs represent a significant economic barrier to market interaction, bear a higher cost of exclusion than identical villagers who have more ready access to markets. In determining the location and size of exclusion zones, forest managers who also consider the impact of their decisions on rural well-being would do well to focus exclusion activities in areas where villagers have low-cost access to markets or substitutes and have high opportunity costs of labour because those villagers can adapt to exclusion policies with relatively low welfare losses.

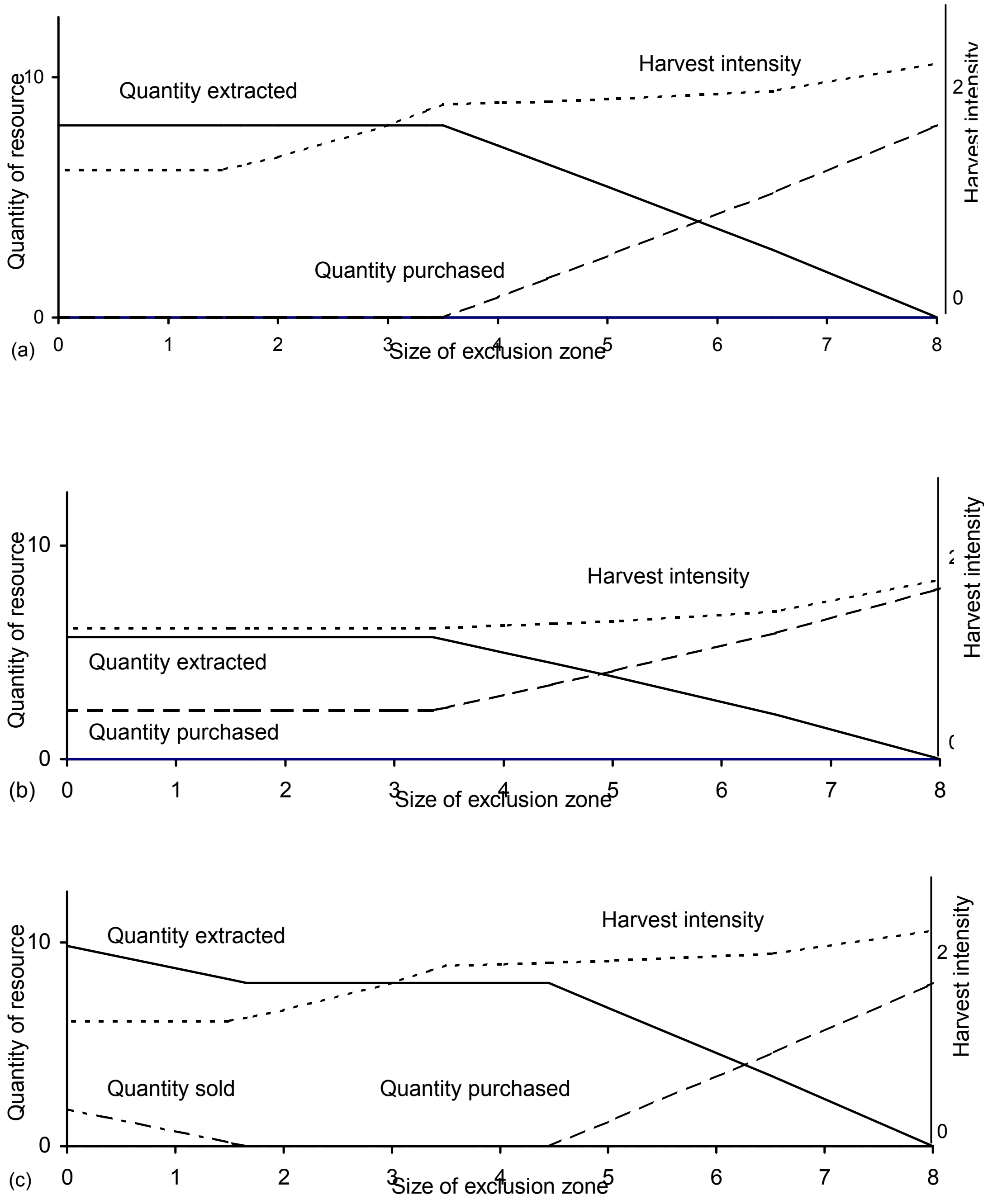

Figure 1: Harvest intensity and dependence on forest and market as a function of the size of the exclusion zone for (a) initially-subsistence villager, (b) initially-supplementing villager, and (c) initially-selling villager

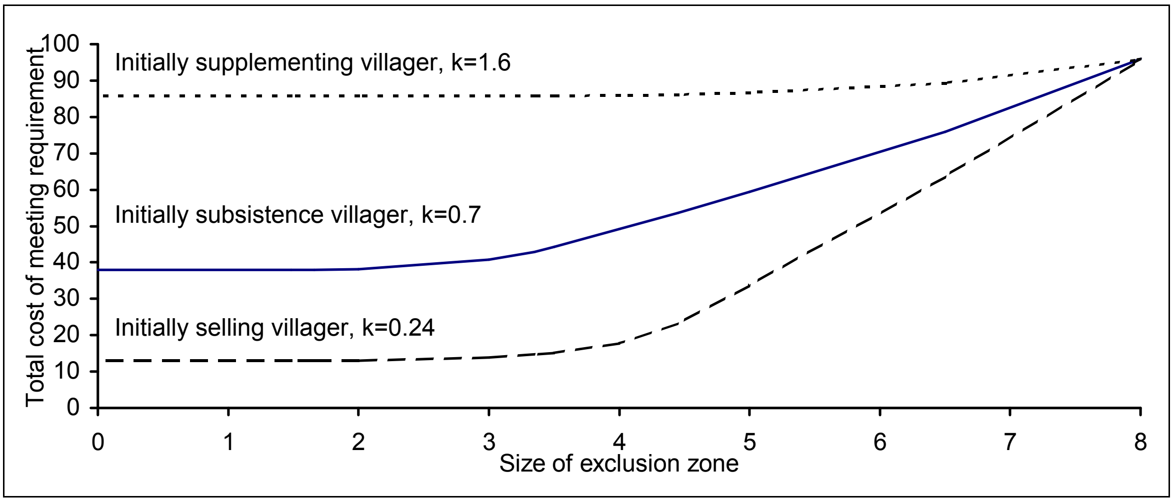

Figure 2a: Costs of meeting requirement R (time costs and purchase costs less any revenues from sales) as a function of twhe size of the exclusion zone.

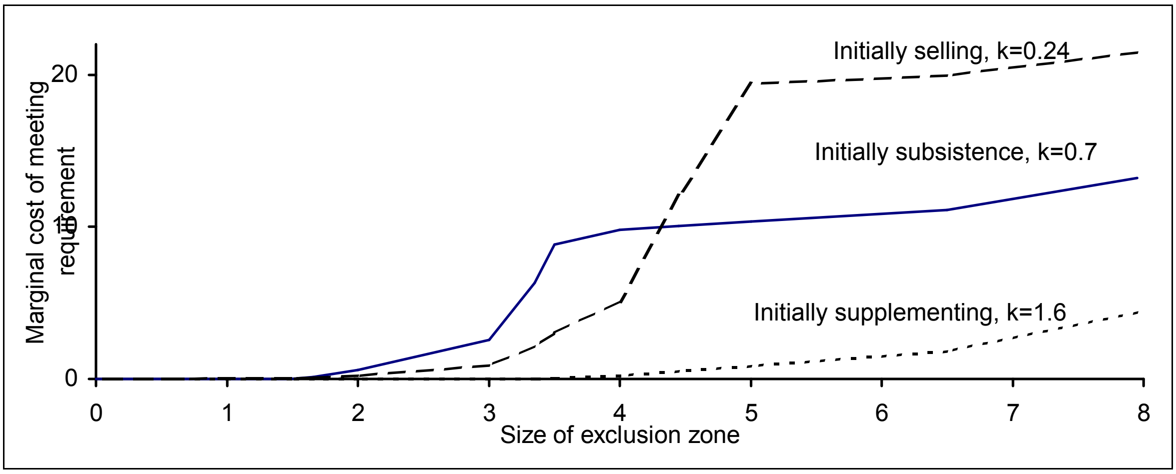

Figure 2b: Marginal cost of meeting requirement R as a function of the size of the exclusion zone.

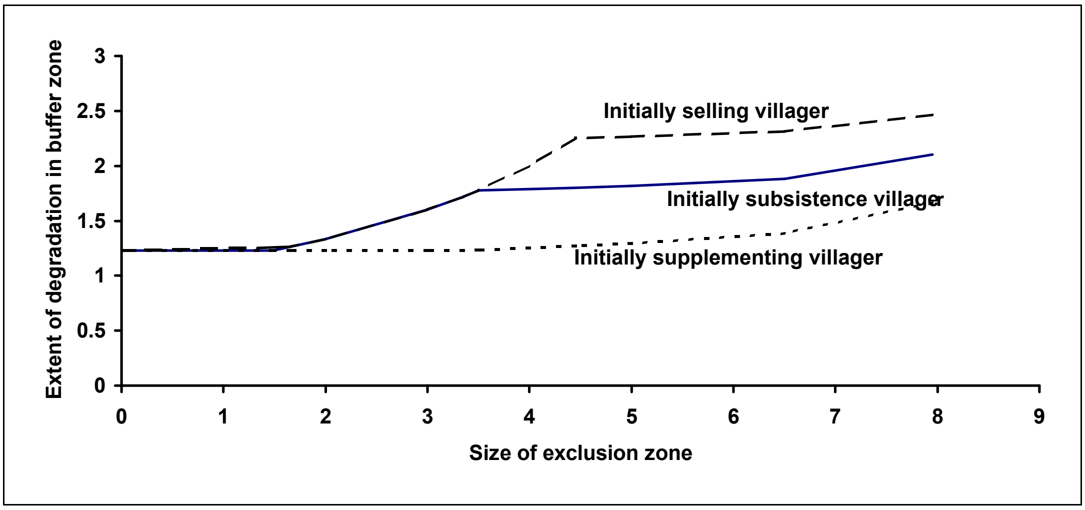

Figure 3: Degradation in the extraction zone as a function of the size of the exclusion zone

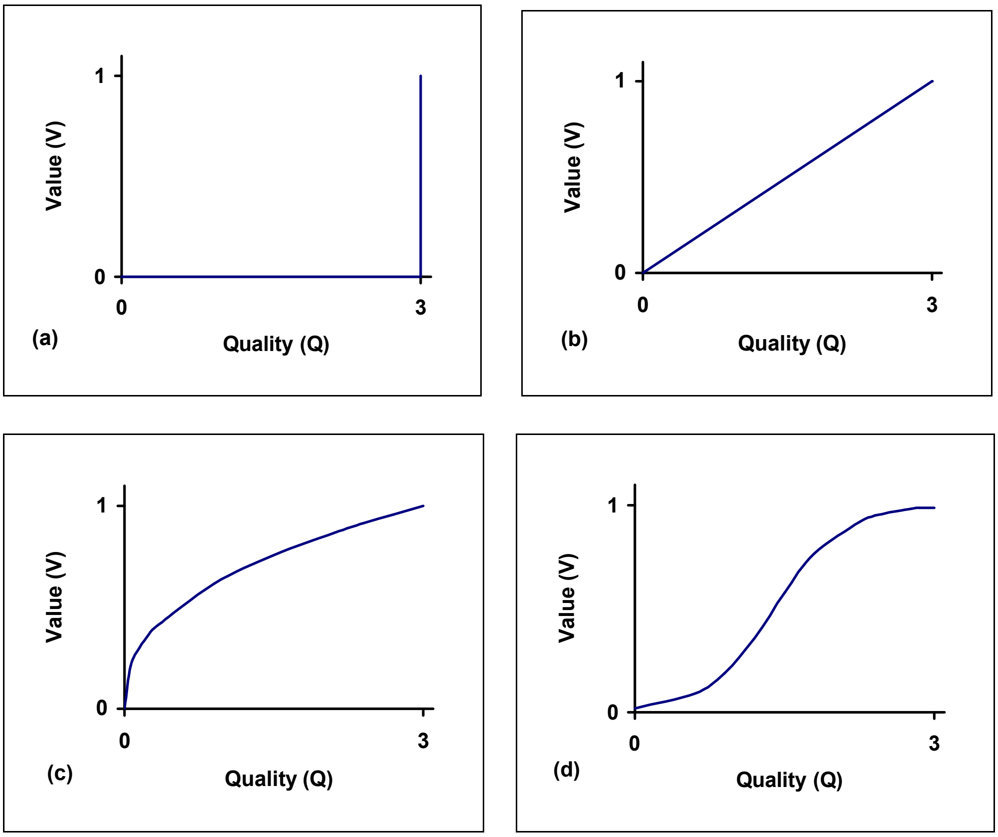

Figure 4. Four alternative "preference functions" for the forest manager (the function used for Figure 4c is: $V = Q^{0.4}$, and for Figure 4d is: $V = 1/\left(1 + 3^{(-8*(Q-0.465))}\right)$

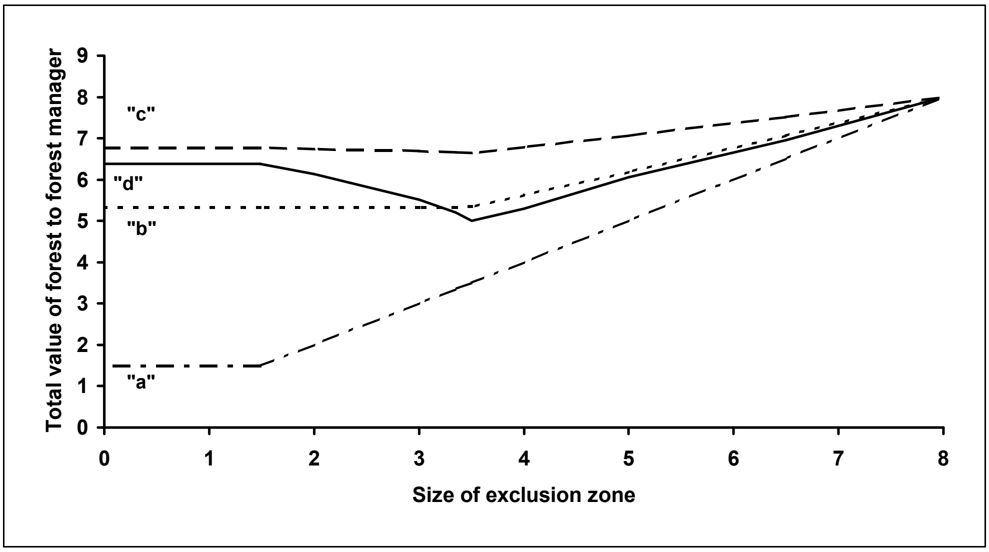

Figure 5. Value of the forest to the forest manager as a function of the four different objective functions, assuming villagers are initially subsistence villagers

Appendix 1:

For the unconstrained subsistence villager:

$$w_i - v = \sqrt{\frac{v}{\beta}}\ ;\ X_i = \frac{R}{m}\frac{\left(1+\sqrt{\beta v}\right)}{\sqrt{\beta v}};\ \text{and}\ h_i = m\left(1-\frac{1}{1+\sqrt{\beta v}}\right)$$

For the unconstrained supplementing villager:

$$w_i - v = \sqrt{\frac{v}{\beta}}\ \text{ and }\ X_i = \left(v+\sqrt{\frac{v}{\beta}}\right)^{-1}\left\{\left[\frac{\beta m(p+y)}{k_i}\left(1+\sqrt{\beta v}\right)^{-2}\right]^{\frac{1}{\gamma-1}} - 1\right\}$$

And for the unconstrained selling villager:

$$w_i - v = \sqrt{\frac{v}{\beta}}\ \text{ and }\ X_i = \left(v+\sqrt{\frac{v}{\beta}}\right)^{-1}\left\{\left[\frac{\beta m(p-y)}{k_i}\left(1+\sqrt{\beta v}\right)^{-2}\right]^{\frac{1}{\gamma-1}} - 1\right\}$$

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