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The impact of buffer zone size and management on illegal extraction, park protection, and enforcement

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ABSTRACT

Many protected areas or parks in developing countries have buffer zones at their boundaries to achieve the dual goals of protecting park resources and providing resource benefits to neighbouring people. Despite the prevalence of these zoning policies, few behavioural models of people's buffer zone use inform the sizing and management of those zones. This paper uses a spatially explicit resource extraction model to examine the impact of buffer zone size and management on extraction by local people, both legal and illegal, and the impact of that extraction on forest quality in the park's core and buffer zone. The results demonstrate trade-offs between the level of enforcement, the size of a buffer zone, and the amount of illegal extraction in the park; and describe implications for "enrichment" of buffer zones and evaluating patterns of forest degradation.

1. Introduction

During the last 30 years, the number of protected areas (PAs) worldwide established to protect natural systems has grown dramatically. Coinciding with that expansion, buffer zones at the boundaries of PAs have increasingly been incorporated into management plans in an attempt to serve the multiple purposes of protecting resources within the park core; providing resource benefits to local people who often must bear the burden of the PA; and desires for PAs to reduce poverty (Dudley, 2008; Naughton-Treves et al., 2005; Wells et al., 1992).[1] For example, UNESCO's Biosphere Reserves incorporate three zones – a core zone, a buffer zone, and a transition area – to achieve conservation, development, and logistical functions (UNESCO, 2011). Recent satellite imagery and inquiries into the effectiveness of parks find high levels of degradation in buffer zones and areas outside of parks (Bruner et al., 2001; DeFries et al., 2005; Martin and Blackburn, 2009). These observations and the absence of appropriate control sites for comparison to in-park sites highlight the need to "study land-use dynamics in areas adjacent to protected areas that are formally designated buffer zones" because they show "more intensive use in buffer zones than in areas further away from the protected area, but causal explanations for this pattern of intensive use are weak or absent" (Naughton-Treves et al., 2005).

Despite increasing recognition of the social and ecological importance of buffer zones and the lack of causal explanations for patterns of degradation, only general guidelines exist to inform decisions over the size of a buffer zone (Dixon and Sherman, 1990; Dudley, 2008; Albers, 2010). Those guidelines may aim specifically at one goal of buffer zones, such as creating a forested distance between habitat and agricultural plots as determined by a species' needs, or providing enough buffer zone forest to provide a subsistence level of fuelwood to neighbours. Even when buffer zone sizing and management decisions effectively address one such goal, however, little analysis of the broader impact of the buffer zone exists such as its effect on degrading and illegal activities within the core zone. Similarly, the interaction and potential trade-offs between the multiple aims of buffer zones have not been addressed in a systematic way. Albers (2010)

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[1] The definition of buffer zones varies but a typical buffer zone permits local people to extract or grow products in a manner that does not threaten the core park areas.

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provides a starting point for investigating the impact of buffer zone size on conservation and rural welfare outcomes by demonstrating theoretically that the width of a buffer zone and the level of enforcement in the core zone can be substitutes, yet this trade-off is not addressed in the literature nor policy. With buffer zones meant to support the general mission of parks including protecting core resources while limiting the burden of parks on local people, a framework that places buffer zones within a broader context provides a basis for buffer zone policy as part of conservation policy.

Building off a series of spatially explicit resource extraction and enforcement models (Albers, 2010; Robinson et al., 2002; and Robinson et al., 2011), this paper examines the impact of buffer zone size, enforcement levels, and enrichment activities on local people's legal and illegal extraction decisions and the resulting levels of park protection and park–people conflict. Following the seminal Becker (1968) framework, our framework incorporates incomplete enforcement, in contrast to complete (Robinson et al., 2011) or no (Robinson et al., 2002, 2008) enforcement. Including incomplete enforcement implies that the model allows for illegal extraction activities in the protected core zone, a central feature of many protected areas. The model is game theoretic in nature, and because it accommodates settings where there are areas with both enforcement and illegal resource extraction, it allows us to explore the possibility of conflict between villagers and park managers (unlike Robinson et al., 2011). In this paper, we focus solely on spatial interactions to explore how management decisions influence the spatial extraction decisions of local people but generalize from the specific geometry of the protected area explored in Albers (2010). Analysis of the spatial extraction model and trade-offs informs buffer zone sizing and management decisions, rather than relying on vague statements about meeting people's needs, creating goodwill, or guessing at appropriate widths (Dixon and Sherman, 1990; Shafer, 1999). We demonstrate that, for example, once incomplete enforcement is a possibility, intermediate sized protected areas surrounded by a buffer zone may result in both a larger pristine area of forest and reduced conflict between villagers and patrollers than a larger protected area with a small or no buffer zone.

Buffer zone management tools include the choice of buffer zone width and enforcement of access restrictions at the buffer zone-park boundary.[2] Empirical studies demonstrate that distance to resources creates an important cost in the resource extraction production function (Kohlin and Parks, 2001; MacDonald et al., 1998; Skonhoft and Solstad, 1996). Buffer zones create a distance between local villagers living at the buffer zone boundary and the park resources, and that distance enters villagers' decisions about extraction locations. Higher levels of enforcement discourage extraction within the park, but parks rarely have sufficient budgets to deter all degrading activities within their boundaries (Bruner et al., 2001; Figueroa and Sanchez-Cordero, 2008). With low budgets, incomplete enforcement leads to illegal extraction within the park boundaries.

In addition to choices over buffer zone width and enforcement levels, management decisions can include "enrichment" of the buffer zone to increase the benefits it provides to local people (e.g. Hjortso et al., 2006) or to reduce illegal extraction within protected areas. For example, Straede and Treue's (2006) analysis of Royal Chitwan National Park in Nepal suggests that illegal activities in the park result from higher resource abundance there and that those activities would not be necessary following enrichment activities in the buffer zone. Because villagers consider buffer zone width, the quality of resources within the buffer zone and core zones, and enforcement in their extraction decisions, effective park management must also consider width, enrichment, and enforcement decisions jointly.

[2] In practice, the size and shape of the buffer zone depend on site-specific characteristics including socioeconomic conditions and threats to the core areas but most buffer zones are contiguous with the core zone.

This paper's next Section 2 describes a spatial extraction model of a non-timber forest product – defined by the Center for International Forestry Research (CIFOR) as "…any product or service other than timber that is produced in forests" (CIFOR, 2011) – that incorporates a villager's response to resource density within the buffer zone and the protected area, and the forest manager's enforcement. Section 3 uses the model to determine the impact of buffer zone width, enforcement, and enrichment activities on extraction, benefits to locals, and degrading activities in the core area. The final section discusses the implications of these results for park and buffer zone siting, sizing, and management decisions and for evaluating park effectiveness.

2. The Model

In our model we envisage a single-dimensional expanse of forest of width X_F. A large number of villagers live adjacent to this forest throughout which a valuable resource is evenly distributed. In the context of Tanzania and several other African countries where forest reforms have been introduced, this forest could be a previously designated government forest that had seen little protection and was now being placed under a new forest management regime such as joint forest management (Persha and Blomley, 2009). In such a situation the extraction of forest resources could be banned in most of the forest but, as we have found in Tanzania's Amani Nature Reserve, the forest manager might allocate some area of the forest to a buffer zone from which resource collection is allowed (Robinson et al., 2011). In our model, the forest manager (or forest management team) chooses how much of the forest to allocate as the protected inner core where resource collection is not permitted (width X_{PA}), and how much to allocate as a buffer zone (width X_B) from which villagers can legally collect resources ($X_B = X_F - X_{PA}$). As such, the forest manager behaves in the same way as the forest manager in Robinson et al. (2011). However, whereas Robinson et al. (2011) assumes perfect enforcement of a protected zone so that extraction only occurs in a buffer zone, in contrast, in this paper we model a more commonly found scenario in which the forest manager cannot under all situations completely deter extraction from the core zone. We therefore allow for the possibility of NTFP extraction occurring in the protected zone, and villagers being caught in this zone and punished. By extending the model to incorporate imperfect enforcement and illegal activities, the model presented and analyzed here identifies the forest manager's trade-offs between buffer zone size, enforcement, and the degree of illegal extraction and degradation within the core zone; trade-offs that models in earlier papers cannot accommodate. By including illegal extraction this paper therefore takes a significant step towards a more realistic setting that more completely represents some of the manager's trade-offs, and identifies areas of potential conflict between villagers and managers. Because the goals in establishing buffer zones include protecting the inner core, providing benefits to local people, and reducing people–park conflict, the model analyzed here provides a more appropriate platform for considering buffer zone sizing decisions than any of our previous models.

2.1. The Forest Manager's Choice

In practice, a forest manager's objective function can include a variety of factors such as the amount of pristine (or no-extraction) forest, the biomass of the landscape, and the welfare of individuals (see Robinson et al., 2011, for a comparison across forest manager objective functions in a similar context but where the core zone is perfectly enforced and all extraction is in the buffer zone). Because the shape and characteristics of the forest manager's objective function can mask the reaction of villagers to a policy and the resulting impact on forest characteristics and rural welfare, we do not make any explicit assumptions about our forest manager's objective function. Rather we parametrically vary the size of the core zone that the forest