Ecological Economics 43 (2002) 261–275

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

ANALYSIS

The local costs of establishing protected areas in low-income nations: Ranomafana National Park, Madagascar

Paul J. Ferraro *

Department of Economics, Andrew Young School of Policy Studies, Georgia State University, University Plaza, Atlanta, GA 30303-3083, USA

Received 21 March 2002; received in revised form 3 September 2002; accepted 17 September 2002

Abstract

Over the last 20 years, governments and influential donor organizations have come to realize that the long-term integrity of protected areas in low-income nations depends critically upon the support of rural communities that live adjacent to them. Despite the recognized need for understanding the opportunity costs of conservation borne by rural communities adjacent to protected areas, there exist few quantitative analyses of the local effects of protected area establishment. Using a unique household data set from southeastern Madagascar, I estimate the opportunity costs borne by residents resulting from the establishment of the Ranomafana National Park in 1991. I conservatively estimate the present value of the opportunity costs to be $3.37 million. The costs are not distributed evenly across households around the park. The average present value of costs per household in four zones around the park ranges from $353 to 1316. These values translate into annual costs per average household of $19 to $70 over a 60-year horizon. The paper also characterizes other costs that were not amenable to empirical estimation. Relative to household incomes in the region, the opportunity costs of conservation are substantial. Relative to the national and global benefits from protecting the rain forests of Ranomafana, however, the costs are quite small and the analysis offers hope that government agencies and international donors can design conservation plans that benefit both endangered ecosystems and the welfare of local communities.

Keywords: Conservation; Opportunity costs; Protected area; Africa

1. Introduction

In the 1980s, governments and influential donor organizations came to realize that the long-term integrity of protected areas in low-income nations depended critically upon the support of rural communities that lived adjacent to them (Anderson and Grove, 1987; Kiss, 1990; West and Brechin, 1991; Brandon and Wells, 1992; Ryan, 1992). Field observations from conservation projects throughout the developing world suggested that the establishment and management of protected areas had substantial negative effects on the livelihoods of residents who lived in and around

* Tel.: +1-404-651-1372; fax: +1-404-651-0425
E-mail address: pferraro@gsu.edu (P.J. Ferraro).

PII: S0921-8009(02)00219-7

protected areas, and thus undermined local support for conservation (e.g., West and Brechin, 1991; Hough, 1991; Kiss, 1990; Anderson and Grove, 1987; Sahama, 1984).

Many academics and practitioners, therefore, have argued that detailed assessments of the local impacts of protected area establishment were a critical missing component in the debate over international conservation policies (Garrat, 1984; Dixon and Sherman, 1990; Ghimire, 1991; Hough, 1991; Winterbottom, 1991; Brown and Wyckoff-Baird, 1992; Geisler, 1993). As Kramer and Sharma (1997) have noted, just as the failure to measure the benefits of biodiversity protection can lead to suboptimal development policies, the failure to measure the local costs of protection may lead to unworkable conservation strategies. An understanding of the local costs of conservation in low-income nations is also important for reasons of equity: those who bear the costs of conservation typically are poor and those who enjoy the benefits typically are rich.

Scientists and practitioners have written hundreds of articles and books documenting the private costs of environmental regulations in high-income nations (recent examples include Berman and Bui (2001) and Lovell and Sunding (2001)). In the context of ecosystem protection in low-income nations, however, relatively little has been written about the nature and magnitude of the local costs of protected areas. Most of what has been written has been anecdotal or non-quantitative with an emphasis on social impacts (e.g., Gordon, 1985; Croft, 1991; Agrawal et al., 1981; Bunting et al., 1991; Schoepf, 1983; Freeman and Frey, 1986; Schelhas, 1991; Payne et al., 1992; Novellino, 1998). There is a dearth of quantitative data on the costs borne by local residents when protected areas are established in low-income nations.

Ruitenbeek (1992) used a mix of primary and secondary data to estimate the opportunity costs to local residents from the continued existence of a National Park in Cameroon. Azzoni and Isai (1994) used secondary data sources to estimate the opportunity costs of ecosystem conservation in Sao Paulo, Brazil over a 60-year time horizon. Norton-Griffiths and Southey (1995) used coarse aggregate data to estimate the opportunity costs of ecosystem conservation in Kenya for a single year. Shyamsundar and Kramer (1996) used contingent valuation techniques to estimate local resident willingness-to-accept restricted resource access associated with the establishment of a National Park in Madagascar. More recently, Kremen et al. (2000) used simple assumptions (based on extensive practitioner knowledge) to estimate the opportunity costs of foregoing industrial logging and hillside agriculture inside a newly designated protected area in Madagascar.

Using a unique household data set from southeastern Madagascar, I estimate the opportunity costs borne by residents resulting from the establishment of a National Park in 1991. My analysis contributes to the sparse literature in several important ways: (1) I use a combination of household surveys and semi-structured interviews to acquire detailed data on resource use and management that existed prior to the establishment of a protected area;[1] (2) I use data on forest use for agriculture and for timber and nontimber forest products (e.g., Norton-Griffiths and Southey had data on foregone agricultural benefits only); (3) I estimate the opportunity costs over time, not just for one year; and (4) I characterize costs both quantitatively and qualitatively.

Relative to household incomes in the region, the estimated local opportunity costs of protecting the Ranomafana National Park (RNP) are substantial. Relative to the national and global benefits from protecting the park, however, the costs are quite small and the analysis offers hope that government agencies and international donors can design conservation plans that benefit both endangered ecosystems and the welfare of local communities.

The next section describes the study site. Section 3 describes the data collection methods. Section 4 develops the conceptual model that provides the analytical basis for the quantitative and qualitative analyses of later sections and describes the empiri-

[1] Most protected area impact assessments have been conducted post facto with no 'pre-park' baseline data (see Geisler, 1993 for survey).

cal approach. Section 5 presents the results of the empirical analysis. Section 4 describes the other costs, as well as some potential benefits, that I was unable to quantify given the data available.

2. Study area

Madagascar provides an appropriate context in which to study the local impacts of protected area establishment. The country is a high priority for global biodiversity protection (Mittermeier et al., 1998), it has experienced high rates of deforestation and resource depletion (Green and Sussman, 1990), and it has recently completed the first two phases of its ambitious 15-year National Environmental Action Plan, which has lead to a substantial increase in the number of strictly protected areas.[2]

Biological species diversity in Madagascar is concentrated primarily in the eastern rain forests (Rakotozafy et al., 1987) of which only one-third of the original area exists (Green and Sussman, 1990). The human communities of the eastern rain forests are rural and almost exclusively agricultural. Residents depend upon forest resources for subsistence and commercial activities. In particular, the forests provide land and biomass for a system of swidden agriculture called tavy, as well as providing myriad timber and non-timber forest products.

Madagascar's Environmental Action Plan gave highest priority to the preservation of the Ranomafana rain forest because of the forest's exceptionally high level of biological diversity and the immediate threat of human activity. In May 1991, the Government of Madagascar established the 41,600-hectare RNP in southeastern Madagascar. The immediate area around the park (within 5 km) is a mosaic of paddy rice fields, hillside agricultural plots, regenerating forest fallow, and, in some areas, relatively intact rain forest. At the time of the park's establishment, there were about 26,000 people living in over one hundred villages within a 5-km radius of the RNP's boundaries. About half of the villages were small, containing 150 people or less.

3. Data collection[3]

From September 1990 through March 1991, I collected data on natural resource exploitation in 22 villages and towns within 3 km of the proposed borders of the RNP. A little over 490 households in 17 villages completed an administered questionnaire, while more than 300 people from the region took part in semi-structured interviews. The household questionnaire documented forest use, agricultural activities and socioeconomic indicators. The semi-structured interview covered topics such as village history, land tenure, and forest collection and agricultural techniques. The interview was designed to complement the household questionnaire by putting the quantitative information from the survey into context. It also served as a means to examine opinions across age, gender, power and economic categories. Visual observations of forest product collection and trade in the region were also recorded.

The household survey was part of a larger health and socio-economic household survey administered by a trained non-governmental team of nurses. In addition to administering the survey, the team, which also included a medical doctor, provided health services. The team's dual role reduced the potential bias in respondent answers that may have been engendered if residents per-

[2] Before 1989, there were only two national parks in Madagascar. In 2001, there were 12. The recent emphasis on 'eco-regional conservation' in Madagascar encourages protection of even larger areas from extractive activities (Freudenberger and Freudenberger, 2000).

[3] More details of the data collection methodology, including copies of the survey instruments, and the results, including household wealth indicators, measures of input and output value, agricultural practices, sociopolitical institutions, resource tenure and the specific species of flora and fauna used, can be found at http://epp.gsu.edu/pferraro/research/workingpaper/workingpapers.htm. The collection and interpretation of data benefited greatly from the substantial assistance of Basile Rakotondrajaona.

ceived the survey to be a ploy by the government to restrict their rights of resource access.

The surveyed region was divided into four zones (Fig. 1). These zones were chosen to include all areas that were inhabited around the park and correspond to ecological, economic and cultural divisions in the region. Surveyed villages were chosen so as to capture the variability of economic and social conditions in each zone. With a few exceptions, every household in each surveyed village completed the questionnaire.

4. Modeling approach

Farm households in the Ranomafana region combine features of both consumers and producers. A farm household is assumed to maximize its utility, which is a function of consumption of market-purchased goods not produced by the household, agricultural goods produced by the household, secondary forest products collected by the households, primary forest products collected by the household, and leisure (see Ferraro, 2001b for formal mathematical model).

The RNP's regulations permit only research and tourism activities within its boundaries and thus lead to a substantial decrease in the amount of forest accessible to local residents for productive purposes. The empirical analysis (Section 5) estimates changes in full income over time that arise because of the RNP's establishment. Full income is the value of the household's time endowment plus the value of the household's production (i.e., agriculture, forest product collection) less the value of the variable inputs required for production of outputs (Singh et al., 1986). Full income is assumed to equal a household's expenditures on the items it consumes (expenditures include both explicit and implicit costs). A decrease in the availability of forest (a fixed input that is combined with labor to produce outputs) will result in

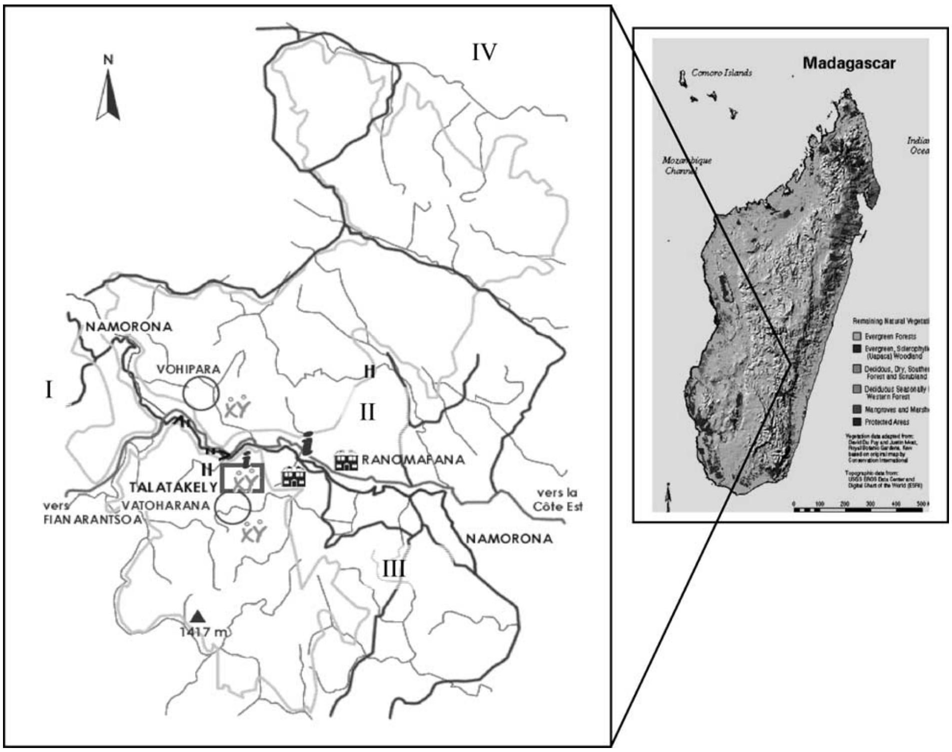

Fig. 1. RNP and Survey Zones I–IV (sources: left map, Association de Gestion des Aires Protégées; right map, Center for Conservation Biology, Stanford University).

lower full income and hence lower consumption of the variables in the utility function. Lower consumption results in a loss of utility, which will be perceived as a cost by local residents.

Changes in household full income are approximated indirectly by estimating the foregone net benefits that the households would have received had the park not been established.[4] The net benefit streams in the presence and in the absence of the RNP are stylized in Fig. 2. The top panel represents the benefit flows coming from the exploitation of the park's resources over time. The curve '$\text{Benefit}_{\text{w/out park}}$' represents the stream of net benefits coming from the exploitation of the RNP's forest in the absence of a National Park. These net benefits increase as residents begin to use more of the park's resources to substitute for the declining ability of the peripheral zone (outside the park) resources to meet local needs. Ultimately, the benefits derived from the use of the park would also decline as the park's resources become degraded. The benefits from exploitation of the park's resources in the presence of the park are assumed to be zero. In other words, the empirical analysis assumes that residents are prevented from exploiting the ecosystems within the RNP as the park decree requires. Recent reports from Ranomafana support the validity of this assumption; since the park's establishment there have been few incursions (Ralimanana, personal communication, 2001.). The potential for local benefits to be generated by the park is addressed in Section 6.

The bottom panel in Fig. 2 represents the benefit flows coming from the exploitation of the park's peripheral zone resources over time. The curve '$\text{Benefitperiph}_{\text{w/out park}}$' represents the stream of net benefits coming from the exploitation of the peripheral zone's resources in the absence of the National Park. These net benefits decrease over time as the resources become more unproductive or depleted (stylized here as a straight line).

[4] A well-functioning land market does not exist in the RNP area, and thus the costs to local residents cannot be approximated using the price of land.

The curve '$\text{Benefit}_{\text{periph w/park}}$' represents the stream of net benefits coming from the exploitation of the peripheral zone in the presence of the National Park. Residents are assumed to substitute for lost park resources through an intensification of peripheral zone resource use.[5] The shaded region A reflects the initial periods of intensification that substitute for lost access to park resources. The shaded region B implies that, in the absence of technological change, this intensification results in a more rapid decline in fertility and loss of secondary forest products and services compared with the no-park scenario (i.e., a more rapid approach to a non-productive state). The assumption of little or no technological change over time is reasonable given: (1) the historically low level of technological improvement in the RNP area, (2) the low level of technological improvement on lands further east that have already undergone a rapid degradation of available resources, and (3) the lack of government extension services in the region. The acceleration of degradation resulting from intensification of lands formerly covered with rain forest is well documented in eastern Madagascar (Razafimamonjy, 1987).

Thus, with the establishment of the RNP, the residents lose the shaded areas of B, C and D, and gain A in Fig. 2. The opportunity costs of establishing the RNP are the present value of $(C+D+B-A)$, or

$$\int_0^\infty e^{-\delta t}\text{Benefit}(t)_{\text{w/out park}}\,dt+$$

[5] There has been little development of off-farm labor opportunities in the RNP area and in areas further east that experienced deforestation decades ago. Development of such opportunities on a large scale in the next several decades is unlikely because of the Ranomafana region's low economic potential and political power, which discourages public and private investment.

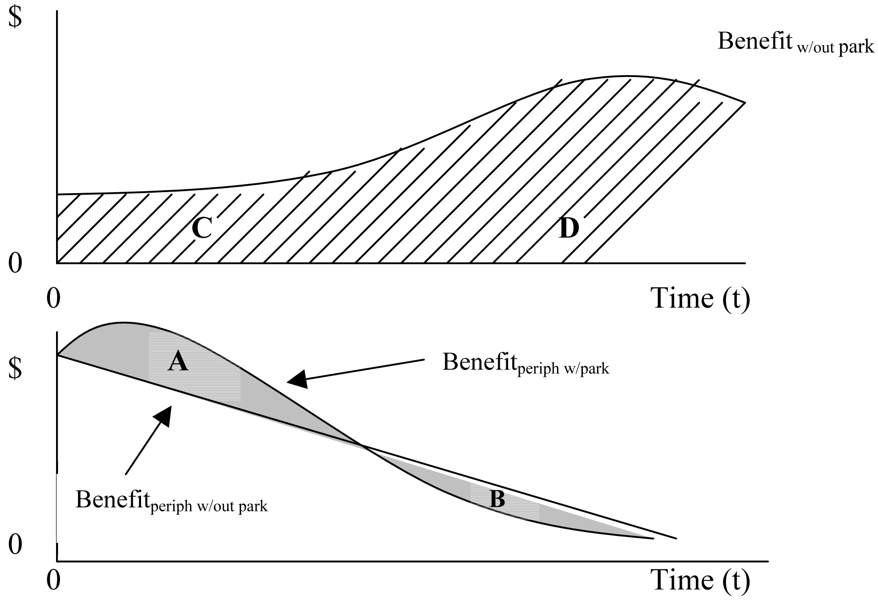

Fig. 2. Net benefit flows with and without the National Park.

$$\int_0^\infty e^{-\delta t}\mathrm{Benefit}(t)_{\mathrm{periph\ w/out\ park}}\mathrm{d}t - \int_0^\infty e^{-\delta t}\mathrm{Benefit}(t)_{\mathrm{periph\ w/park}}\mathrm{d}t,$$

where δ is the discount rate. Estimating only the foregone consumption of resources within the park (i.e., the first integral) could underestimate or overestimate the total opportunity costs, depending on the residents' ability to substitute for the lost resources (present value of A) and the effect that the intensification of resource use has on the longevity of the peripheral zone resources' productive capacity (present value of B). The first and second integral can be estimated with the data available.[6] Estimating the third integral, however, is more difficult. One must predict the likely substitutions to take place in the presence of the park and the effect that these substitutions will have on the long-term productivity of the peripheral zone resources. Although it has been 10 years since the RNP was established, there has been no comprehensive follow-up survey to characterize the changes in resource use since the park's establishment. The empirical analysis will therefore not attempt to estimate the second and third integrals. If one were to assume that that the sum of the second two integrals is greater than zero, the cost estimates in Section 6 are underestimated.

The data used in the modeling consist of (1) the author's point estimates of resource use during the 1990–1991 agricultural calendar based on household questionnaires and semi-structured interviews, (2) resident-revealed historical trends, (3) observations of resident behavior across varying gradients of ecosystem disturbance, and (4) observations of residents in areas further east of the RNP that have already undergone almost complete deforestation. In order to estimate the benefit stream derived from agriculture in the absence of the park, a typical tavy cycle starting with primary forest is estimated for each zone (includes the degradation of the parcel over time) and the net present value of the stream of benefits from the use

[6] Data from one village survey and discussions with local forestry personnel from the heavily deforested region about 40 min east of Ranomafana by car were collected in order to make inferences about likely resident responses to resource degradation over time had the park not been established.

of that piece of land is estimated. Assumptions used to simulate the long-term dynamics in forest product demand and supply, as well as details on the derivation of all other parameter values used in the analysis can be found on the web site listed in [3].

Future resource use patterns in the absence of the park are uncertain. In order to mitigate the effects of uncertainty on the analysis, I use conservative parameter assumptions that likely result in an underestimation of the true costs (e.g., historical trends imply increasing rates of forest exploitation per household over time, but the empirical analysis only permits increasing aggregate rates of exploitation driven by population increases). I also analyze the sensitivity of the results to changes in the assumed parameter values.

The assumed parameter values take resource use in 1990–1991 as the point of reference. During this time, however, much of the forest outside the villages' designated agricultural perimeter was designated as forêt classée (classified forest), in which agricultural use and timber harvesting were regulated by a system of permits (the degree to which the regulations were enforced varied spatially and temporally). Given the existence of forest use regulation prior to the RNP's establishment, it could be argued that if the purpose of the empirical analysis were to estimate the full costs of conservation to local residents, then one must also consider the costs that are incurred through the existing system of forest regulation. The empirical analysis in the next section only measures the costs of changing the status of the regional forest from forêt classée to National Park (i.e., the costs of replacing a system of limited protection with a system of total protection).

5. Empirical results

5.1. Costs per average household

The cost estimates in Malagasy francs (FMG) and in US dollars ($) for the population in each zone within a 5 km belt around the RNP are presented in Table 1. I assume a 5% discount rate (for a justification, see Ferraro 2001a: A.5), a 1900 FMG/$ exchange rate (May 1991 nominal rate), and a 60-year time horizon.[7] The present value of the opportunity costs to residents around the RNP is estimated at 6.4 billion Malagasy francs, or $3.37 million.[8] The average costs per household are $39/year, which is close to the $50/year mean willingness-to-accept estimate obtained by Shyamsundar and Kramer (1996) using contingent valuation in communities around a park north of the RNP.[9]

Although there is no one item in the forest whose loss would substantially affect the average household, the sum total of the value of all the products is substantial. Readers from high-income nations may not consider the costs reported in Table 1 to be high, but one must view them in the context of the low incomes in the RNP region. In 1990, the average annual GNP per capita in Madagascar was $200 (UNICEF, 1992). Historically, the region around the RNP has had lower than average incomes in comparison with other regions in Madagascar (Francois et al. 1967 cited in Pryor, 1990). If it were assumed that annual full income per capita for the average resident in the RNP region was $200, the average annual costs per capita ($6.70) account for over 3% of the annual full income per capita. The range varies across zones from 1.5 to almost 6%. Shyamsundar and Kramer estimate that annual household full incomes in an area of rain forest north of Ranomafana were $279, which would imply costs equal to 14% of household full income on average (range: 7–25%).

Samuel and Rambeloson (1991) estimate that annual cash revenues to the average household in the *firaisina* (county) of Ranomafana amounted to $50–60/year, which implies average annual opportunity costs, from 31 to 139% of total household cash revenues. Thus, although the costs may be small in an absolute sense, they are not negligible

[7] A 60-year horizon is used because even small present values can be substantial to individuals with low incomes.

[8] Up to an additional $850 000 is also lost in foregone local salaries and profits in timber operations in the RNP (Ferraro 2002a).

[9] The 95% confidence interval on their estimate ranged from $10 to 90.

Table 1
Total costs

Zone	Population	Total NPV (FMG)	Total NPV $	Annual costs per household $
Western (I)	6879	735,724,880	387,224	19
Central (II)	5219	1,977,433,762	1,040,755	64
Southeastern (III)	1858	769,435,924	404,966	70
Northern (IV)	11,646	2,923,696,037	1,538,787	35
All Zones	25,602	6,406,290,602	3,371,732	39

Based on a 5% discount rate, a 60-year time horizon, and a 1900 FMG/$ exchange rate. Figures are rounded up to avoid decimals.

relative to current incomes in the region. Given that many residents currently are at or near their minimum full income requirement, and that the costs in Table 1 are likely to be underestimates, the RNP is more detrimental to resident welfare than the values in Table 1 suggest.

Table 1 shows that the magnitudes of the opportunity costs vary across zones. Households in the central and southeastern zones incur more costs than households in the northern and western zones. The composition of the opportunity costs also varies. In some zones, like the west, lost forest products make up the majority of the costs. In other zones, like the southeast, lost access to biomass for tavy makes up most of the costs. Variations across zones are a function of variations in market and wage opportunities (e.g., good market access in central zone), access to primary forest (e.g., good access in southeastern zone), ecosystem characteristics (e.g., lower biomass for tavy in west) and cultural characteristics. Regional differences in opportunity costs and their composition may indicate priorities for internationally-funded conservation and development activities around the RNP.

5.2. Sensitivity analysis

In this section, I examine the degree to which the results presented above are dependent on the assumptions made. As in most empirical analyses, the choice of the discount rate has an important effect on the calculated values. If one assumed that an appropriate discount rate lies between 10 and 3%, the total opportunity costs to residents would lie between $1.39 million and $5.87 million. The discount rate also plays a large role in determining the relative contributions of forgone tavy benefits and forgone forest product benefits to the total costs. As the discount rate increases, the relative importance of the foregone net benefits from forest product collection increases.

The analysis used a population growth rate of 2.25%. Varying the growth rate from 1% to 3%, the total opportunity costs to residents range between $2.97 million and $3.71 million. Given that the assumed population growth rate of 2.25% was computed from data over a 30-year period and that more than 50% of the current population is under the age of 18 years old, the annual population growth rate is likely higher than 2.25%.

Changes in the deforestation rate or the value of net benefits to tavy production affect the cost estimates in the same way. The assumed deforestation rates in the analysis are lower than estimated rates for comparable areas in eastern Madagascar (Green and Sussman, 1990; Ryan, 1992; Green, 1993; CARE/NYZS, 1993; Kramer et al., 1994). If the rates were 50% lower or higher than the assumed rates, the total opportunity costs would lie between $2.23 million and 4.25 million. Forest product collection levels within the RNP were held constant in the analysis, but if collection levels were to increase at the rate of population growth, as is likely, then the total opportunity costs would increase to $4.3 million. If it were assumed that only the population in a 3-km belt around the RNP (16,839) would be affected by the park's establishment, the opportunity costs decrease to \$2.4 million. Changing the time horizon by 25 years either way generates costs between \$2.7 million and \$3.6 million.

The value of labor was calculated based on the timing of each activity as practiced in each zone. If one were to value all labor allocated to tavy agriculture in each zone at the peak wage rate (2400 FMG/day), the total costs decrease to \$2.5 million. If one also were to use peak wages to value the labor allocated to the collection of forest products, the total costs decrease to \$1.8 million. There are few opportunities, however, for peak wage earning outside of harvest time. If one lowered the wage rate for both tavy and forest production collection to the lowest observed wage (650 FMG/day), the opportunity costs increase to \$4.5 million. A variety of other parameters could be varied, including estimated crop yields under tavy production, estimated forest product collection yields, crop prices and forest product prices. In general, changing yields or prices by 25% places the total opportunity costs in the same general range we observed in previous paragraphs: \$2.7–4 million.

In addition to the potential sources of error examined above, the manner in which the data were collected may also have affected the cost estimates. For example, in the northern zone, no villages less than 2 km from the park were surveyed. Residents of villages closer to the park were more likely to use park resources. Given the large number of residents in this zone, underestimation of these costs may significantly affect the overall results. For example, increasing the northern zone deforestation rate by only 0.001 ha/capita and the net benefits from forest product collection by 10% increases the total costs in the northern zone by 21% and the total costs for all zones combined to \$3.71 million. Other sources of bias are described in Ferraro (2001b) and, in general, suggest that the opportunity costs presented in Table 1 should be interpreted as underestimates of the true opportunity costs to residents from the establishment of the RNP. The next section examines potential costs that are more difficult to quantify, but which should be considered when examining the effects of the RNP.

6. Other costs and benefits

6.1. Distributional aspects of costs

The results in Section 5 demonstrate that the costs to residents vary across zones. Residents within these zones, however, are not a homogenous group. Within each zone, there are variations in resource use and thus, there will be variations in costs. There may be intra-zone, intra-village and intra-household differences in the costs incurred by residents, and these variations should be noted. For example, there are two villages in the western zone, Vohiparara and Sahavondronana, where residents were heavily involved in the commercial sale of crayfish and eels. The value of their losses is more like that of residents in the central zone than that of their neighbors in the western zone. The average household in these two villages loses a net present value of \$1014 or \$54/year. The total cost for these two villages is \$59 815, 93% of which is derived from the use of forest products. Thus the values presented in Table 1 mask substantial variations in the costs to residents in each zone. Such variations will make it more difficult for conservation practitioners to address local opposition to the park's existence.

The focus on average households in the analysis also conceals the distributional aspects of the RNP's effects within villages. Some residents depend substantially on the collection of forest products from the park area for income generation during the food deficit period. During this period, households will become more dependent on high-interest consumption loans while their means to repay the loans declines. The establishment of the RNP will particularly hurt poorer households and their descendants because they have little or no access to irrigated rice paddies and hillside land that can substitute for restricted access to park resources. These households and their descendents depend heavily on the 'frontier' outside the agricultural perimeter for their survival. The household data also indicate that wild sources of food and income account for a larger share of household income among the poor than among rich.

The costs are also likely to be spread unevenly across age classes. In the semi-structured interviews, older residents (50+ years) consistently stated that they prefer to engage in tavy because it involves less labor investment and because the work effort is not as strenuous as irrigated paddy work. Young household heads consistently stated that they depend on tavy outside the agricultural perimeter to meet their income need because they have not yet received land through inheritance. Thus even within a village, different groups of residents will be affected in different ways, and this variation will have implications for conservation practitioners (e.g., older residents typically control the communal decision-making institutions).

In the empirical analysis, the household is the unit of analysis. However, studies have shown that, for many decisions, the household should not be treated as a homogenous unit. Dianzinga and Yambo (1991) have shown that the loss of access to forests affects men and women in different ways. Few data exist on individual preferences and the allocation of resources within households in the RNP region. Anecdotal observations, however, suggest that intra-household effects may be important. For example, men tend to be involved in tavy and forest product collection deep in the forest. In order to substitute for the loss of access to forest resources in the park, households will need to invest more in irrigated rice paddies and gardens near villages and in the production of homemade crafts, activities in which women traditionally are the primary laborers.

6.2. Health costs

The establishment of the RNP will affect resident health by affecting the nutritional composition of their diet. For example, the loss of wild protein sources (e.g., 67% of households reported collecting crayfish) will affect health negatively since residents already consume minimal amounts of protein (Hardenbergh, 1993). Samisoa (1992) found that residents in the Ranomafana region depended on cash income to purchase supplemental staples, oils and fats. The loss of income from commercial sales of forest products (e.g., 16% of households reported selling crayfish) will make it more difficult for households to make these purchases.

Changes in cropping patterns in the peripheral zone will also affect nutrition in the area. First, residents will substitute irrigated rice for tavy rice. This substitution is being encouraged by development initiatives associated with the RNP (RNPP, 1996). In Madagascar, Ralambofetra et al. (1986) and Ralambofetra and Rakotovao (1985) found that hillside rice had more protein and more calcium than rice from irrigated paddies. Second, intensification without technological change will lead to fertility decline in the peripheral zone over time. Currently, when the fertility of land declines, households plant less nutritious, but less nutrient-demanding crops such as manioc or sweet potato. Hardenbergh (1993) also found that the quality of the diet deteriorates in the RNP region when other staples are substituted for rice because of the ways in which residents traditionally combine foods in meal preparation.

The establishment of the RNP will also affect the residents' health by affecting access to medicinal plants and health services. Indigenous healers obtain many of their plants inside the dense forests. The loss of cash income as a result of the RNP reduces a household's ability to seek medical care from indigenous healers, government clinics and private pharmacies, all of which require payment. Although most medicinal plants used for self-treatment come from the secondary forest and scrub, there are some plants that come from dense forest in the park. More importantly, the intensification of agriculture and forest product collection in the peripheral zone will tend to increase the scarcity of the desirable medicinal plants for self-treatment over time.

6.3. Social and cultural costs

Residents in the RNP region are very concerned with the fostering of firaisina (union), fihavanana (family) and firaisankina (solidarity). Community harmony is extremely important to because it fosters mutual assistance and security. Any break-down in social relations can lead to economic losses if households are no longer able to work together to take advantage of economies of scale or risk-pooling behavior. In some regions of the world, traditional patterns of authority, reciprocity and social bonds break down in the presence of a protected area that deprives residents of significant resources (Calhoun, 1991). In semi-structured interviews, residents noted that such changes were already occurring in villages before the RNP's establishment (e.g., disregard of taboos on commercial sale of aquatic species; frequent borrowing from richer neighbors that disrupted community harmony). The RNP's establishment may only exacerbate these changes (Narayan et al., 2000: Chapter 6, for an excellent survey of social fragmentation research).

The increase in resource scarcity from the RNP's establishment may also affect resource tenure regimes in the region. Residents manage forest products coming from secondary forests around the village under a common property rights regime. The establishment of the RNP, and its concomitant decrease in the supply of forest products, will increase pressure towards the privatization of secondary forest benefit streams. Such a change in tenure has taken place in the heavily deforested area east of Ranomafana. This change in property rights negatively affects land-poor households who depend upon the secondary forests of other households to collect needed forest products. In particular, single women with children in the RNP region depend upon resources on other residents' land to meet their income needs.

6.4. Exposure to risk

For many residents, intensification on irrigated rice paddies will substitute for foregone tavy yields in the RNP. However, one of the main resident-revealed advantages of tavy is the ability to plant several crops with staggered maturation dates in a single parcel. The differences in maturation dates help residents smooth annual income flows. Residents are unable to do substantial intercropping on irrigated lowlands.

An increase in residents' dependence on rice paddies also exposes risk-averse residents to greater production risk from cyclones, which affect irrigated rice paddies more than tavy plots. Cyclones not only reduce income by damaging each household's crops, but they can also negatively impact households by raising prices. Because of the existence of covariate production risk over the southeastern region, one household's poor harvest would be correlated with diminished aggregate supply and subsequent higher prices.

Substitution in the peripheral zone will also take place through more extensive use of hillsides. In the presence of land scarcity, households in southeastern Madagascar use hilltops for agriculture more frequently. Not only is production lower on these parcels, it is also more variable because of the parcels' exposure to the elements (especially wind). The decrease in peripheral zone fertility over time will also increase the demand for planting manioc, which needs fewer nutrients to grow than most other crops. In some regions, like the eastern central zone, the planting of large areas of manioc is risky because of likely destruction by bush pigs.

Resident exposure to risk is compounded by restricted forest access. Forest products are a reliable resource for substitution when crops fail. The reduction in the regional supply of forest products will increase the risks associated with crop failures, and, for poor households, will increase the probability of falling below the minimum income requirement.

6.5. Benefits to residents from the RNP

The establishment of the RNP may also result in benefits for resident communities, including benefits from tourism, watershed protection and microclimate control. In the decade since the park was established, however, the benefits from tourism have proven to be seasonal and have been captured by a relatively small subset of the population located near the main road, many of whom were not born in the region. Such outcomes from tourism have been shown to occur near many protected areas around the world (Olwig, 1980; Wells et al., 1990; Woo, 1991; Rao and Geisler, 1993; Lindberg et al., 1996; Wallace and Pierce, 1996; Campbell, 1999). Upreti (1985), Mishra

(1982) have documented costs associated with increases in the price of market goods in areas frequented by tourists. Most farmers in the RNP region (~70%) are net buyers of agricultural products and thus price increases are likely to have negative effects on household welfare. Sharing the revenues from park entrance receipts may be one way to more fully distribute benefits from tourism to residents.[10]

The ecological benefits to local residents from protection of the RNP's forest cover are difficult to quantify. Because many of these benefits are long-term and diffusely distributed, residents may not recognize them as benefits. Moreover, the acceleration in peripheral zone degradation resulting from RNP's establishment may result in a number of localized ecological costs in the region, such as increases in iron toxicity from sediment runoff in irrigated paddies. Thus, although ecological benefits to local communities from the park's establishment benefits should be included in a total cost-benefit analysis, they may not mitigate residents' perceptions of their opportunity costs.

One final potential benefit warrants mention. In 1991, the United States Agency for International Development awarded Duke University and the Government of Madagascar $3.237 million to begin improving the management of natural resources inside and outside of the RNP. The Government of Madagascar contributed another $29,000 and other participating organizations contributed $654,000 (USAID/Madagascar 1991). The goal of the project was to integrate the economic development of local communities with the conservation of natural resources inside and outside of the park, thereby engendering local conservation support for the RNP (Duke University, 1990). If one were to assume that 5% of the funds money would be spent on administration, $3.724 million dollars would remain to mitigate the negative effects of the RNP's establishment. Given the cost estimates in Section 5, the funds available would seem to be sufficient for engendering local conservation support.

Unfortunately, reviews of the project's performance do not indicate that the local population realized large benefits. Joseph Peters, former Conservation Technical Consultant with the RNP Project, estimated that less than 2% of the RNP Project's budget went to rural residents around the park; about 55% went to administrative (US-based) overhead and expatriate technical consultants and the rest went to capital expenditures and host-country technical consultants (Peters, 1998). Recent analyses indicate that the effect of these investments on agricultural change in the region has likewise been disappointing (Moser and Barrett, 2002).

7. Conclusion

Madagascar's extraordinary wealth of biodiversity is being liquidated rapidly. Strong measures are needed to ensure the preservation of this wealth for the future. These measures will inevitably include the use of protected areas. However, the same ecosystems that are top priorities for conservation provide adjacent resident communities with many valuable goods and services on which their lives depend. Without alternative methods of meeting these needs, restricted access to protected ecosystems will mean diminishing standards of living over time for communities adjacent to protected areas. Diminishing local welfare may generate serious conflicts between protected area managers and the resident population and thus jeopardize the long-term conservation goals of protected areas. In order to identify and reduce these conflicts, the local costs of protected areas must be estimated.

Using data from southeastern Madagascar, I estimate that the present value (1991 dollars) of opportunity costs to local residents from the establishment of the RNP is $3.37 million. In addition to these costs, there were other costs that I was unable to quantify, including health, cultural and social costs. Although I was unable to quantify these additional costs, there is no reason

[10] In 1996 the RNP was one of the most popular parks in Madagascar and received about 6000 tourists (Vieta, 1998), but a majority of visitors were Malagasy nationals who paid less than $1 to enter the park (foreigners paid 50 000 FMG, which was about $12 in 1996).

to believe that they are inconsequential. Relative to household incomes in the region, the total opportunity costs of local communities from the establishment of the RNP are substantial.

On a national and global scale, however, the benefits from protecting the RNP are likely to be far greater than the opportunity costs of local residents. The park has been characterized as a biological paradise with many endangered and exotic endemic species. As a tourist site, the park has much potential for generating benefits at the regional, national and international level. Furthermore, the RNP protects the watershed of a hydroelectric plant that generates electricity for the entire central southeastern region, including the provincial capital city. The analysis by Kremen et al. (2000) suggests further benefits from carbon sequestration.

Although the conservation funds that were invested in the Ranomafana region in 1990s ($3.92 million) did not mitigate the local opportunity costs from the park's establishment, my analysis suggests that those funds could have indeed encouraged local conservation support were they spent differently (e.g., as conservation performance payments; Ferraro, 2001c). If the opportunity costs of conservation throughout Madagascar are similar to those in Ranomafana (as suggested by the analysis of Shyamsundar and Kramer), conservation practitioners can take comfort knowing that the obstacles to conservation in a biodiversity hotspot like Madagascar are not insurmountable.

Acknowledgements

The author gratefully acknowledges field support from UNESCO's Man and the Biosphere Program, Patricia Wright, Basile Rakotondrajaona and Lon Kightlinger, and analysis support from the United States Agency for International Development. Useful comments on previous drafts were provided by Ron Cummings, Paul Hanson, Sabrina Hardenbergh, Bruce Johnson, Robert Kellison, Randy Kramer, Robert Healy, Evan Mercer, Joseph and Dai Peters, Daniel Razafimamonjy, Kristin Rowles, Dan Turk and three anonymous reviewers.

References

Agrawal, B., Reddy, G., Suchaker, N., 1981. An experiment in action anthropology: Yanadi action research project in India. Human Organization 40, 87–90.

Anderson, D., Grove, R., 1987. Conservation in Africa: People, Policies, and Practice. Cambridge University Press, Cambridge, UK.

Azzoni, C.R., Isai, J.Y., 1994. Estimating the costs of environmental protection in Brazil. Ecological Economics 11 (2), 127–133.

Berman, E., Bui, L.T.M., 2001. Environmental regulation and productivity: evidence from oil refineries. Review of Economics and Statistics 83 (3), 498–510.

Brandon, K., Wells, M., 1992. Planning for people and parks: design dilemmas. World Development 20 (4), 557–570.

Brown, M., Wyckoff-Baird, B., 1992. Designing Conservation and Development Projects. Biodiversity Support Program. Washington, DC.

Bunting, W.B., Sherpa, M.N., Wright, M., 1991. Annapurna conservation area: Nepal's new approach to protected area management. In: West, P.C., Brechin, S. (Eds.), Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press, Tucson, AZ.

Calhoun, J.B., 1991. The plight of the Ik. In: West, P.C., Brechin, S. (Eds.), Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press, Tucson, AZ, pp. 55–60.

Campbell, L.M., 1999. Ecotourism in rural developing communities. Annals of Tourism Research 26 (3), 534–553.

CARE International-Madagascar and The New york Zoological Society/The Wildlife Conservation Society (CARE/NYZS),1993. Masoala Integrated Conservation and Development Project.

Croft, T.A., 1991. Lake Malawi National Park: a case study in conservation planning. In: West, P.C., Brechin, S. (Eds.), Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press, Tucson, AZ.

Dianzinga, S., Yambo, P., 1991. Les femmes et la forêt: utilisation et conservation des resources forestières autre que le bois. In: Cleaver, et al. (Eds.), Conservation of West and Central African Rainforests. World Bank, Washington, DC, pp. 233–238.

Dixon, J.A., Sherman, P.B., 1990. Economics of Protected Areas: A New Look at Benefits and Costs. Island Press, Washington, DC.

DukeUniversity, 1990. Ranomafana National Park: Integrating Rainforest Conservation with Sustainable Development in

Madagascar. A grant proposal to the USAID mission to Madagascar. Duke University, Durham, NC.
Ferraro,P.J., 2001a. The Local Costs of Establishing Protected Areas in Low-Income Nations: Ranomafana National Park, Madagascar. Environmental Policy Working Paper no. 2001-006 (unpubl.). Dept. of Economics, Andrew Young School of Policy Studies, Georgia State University, Atlanta, GA.
Ferraro, P.J., 2001b. Natural resource use in the southeastern rain forests of Madagascar. Environmental Policy Working Paper no. 2001-007 (unpubl.). Dept. of Economics, Andrew Young School of Policy Studies, Georgia State University, Atlanta, GA.
Ferraro, P.J., 2001c. Global Habitat Protection: limitations of development interventions and a rle for conservation performance payments. Conservation Biology 15(4), 990–1000.
Francois, P.J., Commisariat général au plan, Institut national de la statistique et de la recherche économique, 1967. Budgets et alimentations des ménages ruraux, Rapport de synthèse. Paris: Imprimerie SPIT.
Freeman, D.M., Frey, R.S., 1986. A Method for assessing the social impacts of natural resource policies. Journal of Environmental Management 23, 229–245.
Freudenberger, M.S., Freudenberger, K.S., 2000. Contradictions in Agricultural Intensification and Improved Natural Resource Management: issues in the Fianarantsoa Forest Corridor of Madagascar. LDI Program Presentation to USAID-Nairobi.
Garrat, K., 1984. The relationship between adjacent lands and protected areas: issues of concern for the protected area manager. In: McNeeley, J., et al. (Eds.), Conserving the World's Biological Diversity. IUCN, WRI, CI, WWF-US, and World Bank, Washington, DC, pp. 65–71.
Geisler, C.C., 1993. Rethinking SIA: why ex ante research isn't enough. Society and Natural Resources 6, 327–338.
Ghimire, K.B., 1991. Parks and People: Livelihood Issues in National Parks: Management in Thailand and Madagascar. United Nations Research Institute for Social Development. Discussion Paper.
Gordon, R.J., 1985. Conserving bushmen to extinction in southern Africa. Survival International Annual Review 44, 28–42.
Green, G.M., 1993. Remotely Sensed Determination of Deforestation History and Topographic Controls: Mantady National Park and Surroundings. Photocopy.
Green, G., Sussman, R., 1990. Deforestation history of the eastern rain forests of Madagascar from satellite images. Science 248, 212–215.
Hardenbergh, S.H.B., 1993. Undernutrition, Illness and Children's Work in an Agricultural Rain Forest Community of Madagascar. Ph.D. Dissertation, University of Massachusetts.
Hough, J., 1991. Social impact assessment: its role in protected area planning and management. In: West, P.C., Brechin, S. (Eds.), Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press, Tucson, AZ, pp. 274–282.
Kiss, A., 1990. Living with Wildlife: Wildlife Resource Management with Local Participation in Africa. Washington, DC: World Bank.
Kramer, R.A., Sharma, N., 1997. Tropical forest biodiversity protection: who pays and why. In: Kramer, R., van Schaik, C., Johnson, J. (Eds.), Last Stand: Protected Areas and the Defense of Tropical Biodiversity. Oxford University Press, New York, NY, pp. 162–186.
Kramer, R.A., Sharma, N, Shyamsundar, P., Munasinghe, M., 1994. Cost and Compensation Issues in Protecting Tropical Rainforests: Case Study of Madagascar. Environment Working Paper no. 62. Washington, D.C.: World Bank, Environment Department, Africa Technical Department.
Kremen, C., Niles, J.O., Dalton, M.G., Daily, G.C., Ehrlich, P.R., Fay, J.P., Grewal, D., Guillery, R.P., 2000. Economic incentives for rain forest conservation across scales. Science 288, 1828.
Lindberg, K., Enriquez, J., Sproule, K., 1996. Ecotourism questioned: case studies from Belize. Annals of Tourism Research 23 (3), 543–562.
Lovell, S.J., Sunding, D.L., 2001. Voluntary development restrictions and the cost of habitat conservation. Real Estate Economics 29 (2), 191–220.
Mishra, H.R., 1982. Balancing human needs and conservation in Nepal's royal Chitwan Park. Ambio 11 (5), 246–251.
Mittermeir, R.A., Myers, N., Thompsen, J.B., Fonseca, G.A.B., Olivieri, S., 1998. Global biodiversity hotspots and major tropical wilderness areas. Conservation Biology 12, 516–520.
Moser, C.M., Barrett, C.B., 2002. Labor, Liquidity, Learning, Conformity, and Smallholder Technology Adoption: the case of SRI in Madagascar. March (unpublished). Cornell University, Ithaca, NY.
Narayan, D., Patel, R., Schafft, K., Rademacher, A., Koch-Schulte, S., 2000. Voices of the Poor: Can Anyone Hear Us?. Published for the World Bank, Oxford University Press, New York, NY.
Norton-Griffiths, M., Southey, C., 1995. The opportunity costs of biodiversity conservation in Kenya. Ecological Economics 12 (2), 125–139.
Novellino, D., 1998. Sacrificing peoples for the trees: the cultural cost of forest conservation on Palawan Island (Philippines). Indigenous Affairs 4, 4–14.
Olwig, K.F., 1980. National parks, tourism, and local development: a west Indian case. Human Organization 39 (1), 22–31.
Payne, R.J., Rollins, R., Tamm, S., Nelson, C., 1992. Managing social impacts of parks and protected areas in northern Canada. In: Wison, H.H., et al. (Eds.), In Science and the Management of Protected Areas. Elsevier V Science, Amsterdam, pp. 513–518.
Peters, J., 1998. Transforming the integrated conservation and development approach: observations from the Ranomafana National Park Project. Journal of Agricultural and Environmental Ethics 11, 17–47.

Pryor, F.L., 1990. The Political Economy of Poverty, Equity, and Growth: Malawi and Madagascar. Oxford: Oxford University Press.

Rakotozafy, A., Dorr, L., Gentry, A., 1987. La biodiversité à Madagascar. In: Mittermier, R.A., et al. (Eds.), Priorites en Matiere de Conservation des Especes a Madagascar. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Ralambofetra, E., Rakotovao, L.H., 1985. Étude de la valeur nutrionelle de different variétés de riz de Madagascar-Les proteines du riz. Recherche pour le développement. Serie Sciences biologiques, no.2, deuxième semestre, MRSTD: 141-155.

Ralambofetra, E., Rakotovao, L.H., Bayomoue, G., 1986. Étude de la valeur nutrionelle de different variétés de riz de Madagascar-Les éléments minéraux du riz: Teneur en éléments mineraux. Recherche pour le développement. Serie Sciences biologiques, no.3, MRSTD: 115-135.

Rao, K., Geisler, C., 1993. The social consequences of protected areas development for resident populations. Society and Natural Resources 3, 19–32.

Razafimamonjy, D., 1987. Contribution à l'étude de la dynamique du savoka dans la région de Ranomafana-Ifanadiana. Mémoire de diplôme d'études approfondies de sciences biologiques appliquées. Université de Madagascar, Antananarivo, Madagascar.

Ruitenbeek, H.J., 1992. The rainforest supply price: a tool for evaluating rainforest conservation expenditures. Ecological Economics 6, 57–78.

Ryan, J.C., 1992. Life Support: Conserving Biological Diversity. Worldwatch Paper 108. Washington, DC: Worldwatch Institute.

Sahama, V.B., 1984. Human dimensions in wildlife management: the Indian experience. In: McNeeley, J., et al. (Eds.), Conserving the World's Biological Diversity. IUCN, WRI, CI, WWF-US, and World Bank, Washington, DC.

Samuel, R., Rambeloson, M., 1991. Résultats enquête socioeconomique. Firaisina de Ranomafana. Program d'actions integrées pour la suivie et le développement de l'enfant. UNICEF.

Schelhas, J.W., Jr. 1991. Socio-economic and biological aspects of land use adjacent to Braulio Carrillo National Park, Costa Rica. Ph.D. Dissertation, University of Arizona, Tucson.

Schoepf, B.G., 1983. Unintended consequences and structural predictability: man and biosphere in Zaire's Lufira Valley. Human Organization 42, 361–367.

Shyamsundar, P., Kramer, R.A., 1996. Tropical forest protection: an empirical analysis of the costs borne by local people. Journal of Environmental Economics and Management 31 (2), 129–144.

Samisoa, M., 1992. Socioeconomic Diagnostic Survey in Periphery Zone of the Ranomafana National Park. Unpublished manuscript. Department of Sociology, National Center for Research on the Environment, Antananarivo Madgascar.

The basic model: theory, empirical results, and policy conclusions.Singh, I., Squire, L., Strauss, J., et al. (Eds.), Agricultural Household Models: Extensions, Applications, and Policy. The John Hopkins University Press, Baltimore, MD 1986, pp. 17–47.

UNICEF, 1992. State of the World's Children. Oxford, UK: Oxford University Press.

United States Agency for International Development (USAID-Madagascar), 1991.USAID/MadagascarEnvironment Program. Antananarivo, Madagascar.

Upreti, B.N., 1985. The park-people interface in Nepal: problems and new directions. In People and protected areas in the Hindu Kush-Himalaya: proceedings of the International Workshop on the Management of National Parks and Protected Areas in the Hindu Kush-Himalaya held on 6-11 May 1985 at Kathmandu, Nepal. In: McNeely, J.A.; Thorsell, J.W., Chalise, S.R. (Eds.), 19-24, Kathmandu, King Mahendra Trust for Nature Conservation and the International Centre for Integrated Mountain Development.

Vieta, F., 1998. Ecotourism propels development but social acceptance depends on economic opportunities for local communities. Africa Recovery 13 (1), 1–2.

Wallace, G.N., Pierce, S.M., 1996. An evaluation of ecotourism in Amazonas, Brazil. Annals of Tourism Research 23 (4), 843–873.

Wells, M., Brandon, K., Hannah, L., 1990. People and Parks: Linking Protected Area Management with Local Communities. World Bank, World Wildlife Fund, and USAID. Washington, DC.

West, P.C., Brechin, S.R. (eds.), 1991. Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press.Tucson, AZ.

Winterbottom, R., 1991. Tropical forestry action plans and indigenous people: the case of Cameroon. In: Cleaver, K., et al. (Eds.), Conservation of West and Central African Rainforests. World Bank, Washington, DC.

Woo, H.T., 1991. An assessment of tourism development in the national parks of South Korea. In: West, P.C., Brechin, S. (Eds.), Resident Peoples and National Parks: Social Dilemmas and Strategies in International Conservation. The University of Arizona Press, Tucson, AZ.