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PROTECTED AREAS, WILDLIFE CONSERVATION AND LOCAL WELFARE

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by

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Abstract

The establishment and expansion of protected areas in Africa have been motivated by the aspiration of increased wildlife abundance. During the past decades, however, this practise has been subject to a massive debate. While some claim that protected areas have failed in preserving African wildlife, others claim that existing protected areas are successful. This paper adds to this debate by presenting a bio-economic analysis of protected area expansion. The model considers a hunter-agrarian community located on the border of a protected area. An expansion of the protected area means less land for agricultural cultivation and hunting. Depending on the economic conditions in these activities, it is demonstrated that protected area expansion may reduce the degree of wildlife conservation. In addition, it may reduce the welfare of the local people.

Key words: protected areas, wildlife conservation, hunting, agriculture, local welfare

1. Introduction

The initial approach to preserve natural resources in Africa had its roots in the Western environmentalist movement of the 20th century. This approach saw the establishment of large areas of national parks and reserves as the foremost priority for African conservation ([16], [19] and [31]). The objective of this management system was to protect wild animals and natural habitats through prohibition or restriction of wildlife utilization. Setting aside areas for national parks and game reserves is still the predominating management strategy ([31]). The control and management of protected areas are usually vested in the State, which reaps economic benefits from wildlife tourism. In contrast, gazetting land for wildlife protection has displaced rural communities and curtailed their access to natural resources that they previously had access to. Land for cultivation and pasture has been lost and harvesting of wildlife in these areas has been deemed illegal ([16], [19], [31], and [33]). In addition, local communities bear the costs of living with wildlife through agricultural damage induced by animals roaming on agricultural land. Hence, while the State reaps the benefits of protected areas, the costs are borne at the local level.

The idea of protected areas was motivated by the aspiration of increased wildlife abundance. The continuing expansion of protected areas in Africa reflects that this perception is still prevalent. However, the increasing poaching pressure has led to a growing recognition that protected areas have failed in their goals of preserving wildlife ([12], [16], [20] and [30]-[31]). Martin [20], for instance, claims that Africa has made the mistake of gazetting too many and too large areas to be able to meet the minimum operating costs required in order to conserve and protect wildlife in these areas. He pictures an inevitable situation where budgets are to small to prevent illegal exploitation, leading all areas to deteriorate simultaneously (see also [11] and [17]).

Other critics of protected areas have pointed to the unfairness of excluding local people from access to parks and natural resources they have used for centuries. Kiss [16] and Swanson and Barbier [31], among others, argue that the lack of economic compensation to local people for loss of access has led to a failure of protected areas. They argue that it is necessary to correct this distortion in order to promote wildlife conservation, and suggest that this is achievable through revenue sharing in wildlife related activities. They believe that local people will respond to such benefits by reducing the exploitation of wildlife[1]. Such and other initiatives to promote sustainable development in surrounding areas are today widespread through Integrated Conservation and Development Projects (ICDPs). See, e.g., van Schaik and Rijksen [32] for an overview of the history of ICDPs.

Although the critique of parks is massive, others claim that protected areas work well. Bruner et al. [5] compare the current conditions inside parks with their surrounding areas and find that parks are better conditioned than their surrounding areas. In case of hunting, they find that the impact of this activity on wildlife in parks is considerably less compared with surrounding areas. However, Bruner et al. [5] do not investigate the effectiveness of protected areas with respect to the total wildlife population, that is, the sum of wildlife living in the protected area and its surroundings. Because wildlife often migrates over large areas, this raises the question whether hunting in outer areas can prove to make protected areas counterproductive, even if wildlife management authorities were to succeed in defending protected areas against intrusion.

This question is the starting point of the present paper. The paper presents a bio-economic model where wildlife disperses over a fixed area or ecosystem. The ecosystem contains two sub-areas, the protected area and the surrounding area. In the surrounding area a group of local peasants utilize the outer land for agricultural production and wildlife hunting. Hence, there are two alternative uses of protected land, namely as input in agricultural production and as hunting ground. It is further assumed that hunting is not allowed in the protected area and that law enforcement is effectively preventing illegal hunting here. However, the local people have legal rights to exploit the land in the outer area and wildlife roaming outside the park. That is, they have user rights to land and wildlife in the outer area[2]. Finally, the size of the protected area is determined by the State and considered as exogenous in the model. Within this setting, this paper aims at investigating the impact of an exogenous expansion of a protected area on the total wildlife stock and the welfare of the local people.

This paper is an extension of the research of marine reserves presented by Conrad [10], Hannesson [13], Pezzey et al. [23], and Sanchirico and Wilen [25]. Sanchirico and Wilen [24], for instance, consider two fishing patches, initially characterised as open-access fisheries (entry until zero rents)[3]. A marine reserve is created by closing one patch for fishing. The fish stock in the open patch is determined by a fixed cost-price ratio and is not altered by closing the other patch. Based on these assumptions, a marine reserve increases the aggregate biomass of the two patches for every ecological system.

Sanchirico and Wilen [25] also focus on the economic impact of a marine reserve. Because free access to the open patch means zero rent, they define the fishery as better off if a marine reserve increases the total harvest. As the fish stock disperses between the patches, they show that the effect on total harvest of closing one patch is positive if increased dispersal between the reserve and the open patch compensates for the foregone harvest in the reserve. Also Hannesson [13] shows that marine reserve creation increases the aggregate fish stock when there is open access to the area outside the reserve. However, he demonstrates that a marine reserve of a moderate size will have only a small conservation effect, compared with open access to the entire area inhabited by the stock. In addition, he shows that the impact on the aggregate catch depends on the size of the marine reserve.

Marine habitats, however, differ from terrestrial habitats in that there are no alternative uses of marine reserves. In order to draw a line to marine reserves, this paper makes a distinction between two policies of land protection. The difference between these policies lies in the *type* of land gazetted. One alternative is to establish a protected area by gazetting non-cultivated land only. In such a case, there is no alternative use of the protected area except hunting. This policy is therefore quite similar to marine reserve creation and the analysis demonstrates that it promotes wildlife conservation. The mechanism works through the allocation of labour between agriculture and hunting: Restricted hunting grounds reduce the labour productivity in hunting relatively to the productivity of labour in agriculture. Consequently, the local people will respond to a protected area expansion by devoting less labour towards hunting.

However, rapid human population growth in Africa has forced humans to bring their agricultural activities ever more close to wildlife habitats (see [11] and [20]). The second alternative is therefore to expropriate cultivated land for wildlife protection. In this case the protected area does not only close off an area for hunting, it also withdraws land previously used in agriculture. Consequently, an additional alternative cost of habitat protection is present, namely the foregone return from crop production. The analysis shows, in contrast to marine reserves, that this policy may cause wildlife degradation: If the impact of reduced hunting grounds on labour productivity in hunting is low compared with the impact of less agricultural land on labour productivity in agriculture, then land expropriation leads the local people to increase the input of labour in hunting. Increased hunting pressure in the outer area may then reduce the wildlife stock.

The rest of this paper is organized as follows. Section 2 presents the ecological model, while the behaviour of the local people follows in section 3. The impact on wildlife conservation and local welfare of protected area creation is investigated in section 4. A summary and discussion follows in section 5.

2. The ecological model

Consider an area or ecosystem of fixed size divided in two sub-areas; a protected area and an outer area. The ecological modelling is identical to Hannesson [13] who looks at species dispersing between the sub-areas in a density-dependent way. This means that wildlife migrate to the relatively less dense area (see e.g., [24]). Because there are no physical obstructions, e.g. fencing, separating the parkland from the open area, animals roam freely between the sub-areas. It is further assumed, as already mentioned, that wildlife harvesting only takes place when the species are outside the protected area.

In the following, some restrictive assumptions are made about the quality of land. First, land is considered homogenous, i.e. every part of the ecosystem is equally suitable as habitat for wildlife. Secondly, although agricultural production takes place in the outer area, it is assumed to be no incompatibility in land use. That is, there is no negative impact on the living conditions of wildlife of adding more land to agricultural production[4]. However, in reality, unexploited land may generate more wildlife than agricultural land as land clearing, fencing and so forth result in poorer conditions and smaller refuges for wildlife (see [22]). This may be captured, as in Huffaker et al. [15], by assuming a smaller intrinsic growth rate of wildlife in the outer area. However, in order to take a first step into the main issue presented here, no incompatibles in land uses are assumed to be present. See also section 5.

The purpose of this paper is to analyse the conservation effect of altering the size of the protected sub-area. An increase in the size of this area is followed by an equal reduction in the outer area. Because of this, the migration rates between the sub-areas are specified as dependent on the size of the respective areas. Technically, the probability of an animal being located in the protected area or the outer area equals the size of the respective areas. Now, assume that the size of the ecosystem is normalized to one. A fraction w of this area is gazetted as protected land and consequently, $(1-w)$ is the size of the outer area. Let $X(t)$ be the density of the stock in the protected area at time t, while $Y(t)$ is the density in the outer area at time t. In the following, the time subscript is omitted. The size of the wildlife stock in the protected area and the outer area is wX and $(1-w)Y$ respectively, so that the aggregate stock equals $S = wX + (1-w)Y$.

Let $z \geq 0$ be the moving rate of wildlife, i.e. the rate at which an animal moves to bring it to the nearest suitable spot for grazing or prey[5]. $z = 0$ means that the animals do not move around at all. The rate of dispersal of the stock in the protected area is then zwX. $(1-w)$ is the probability that the moving animal will migrate out of the reserve. The migration out of the reserve is therefore $z(1-w)wX$. To translate this into change in stock *density* in the outer area, we divide it by the size of that area. Hence, the increase in the density of wildlife in the outer area due to migration from the protected area is zwX. Similarly, $zw(1-w)Y$ is the migration from the outer area onto protected land. The reduction in the density of wildlife in the outer area due to migration to the conservation area is then zwY. In the same way, the change in the stock density in the conservation area due to migration from the outer area is

$z(1-w)Y$, while the stock density in the conservation area is reduced by $z(1-w)X$ due to migration to the outer area.

Because of the non-incompatibility of land, the carrying capacity per square kilometre is equal in each sub-area and therefore normalized to one. Natural growth is assumed to take place in both sub-areas and is given by a logistic growth function. The rate of change in the density of wildlife in the two sub-areas is given by

(1) $$dX/dt = rX(1-X) + z(1-w)(Y-X)$$

(2) $$dY/dt = rY(1-Y) + zw(X-Y) - h$$

Here, h is the harvesting rate, while r is the intrinsic growth rate. Note that the rate of change in the aggregate stock is given by $dS/dt = wdX/dt + (1-w)dY/dt$. If the whole ecosystem is gazetted for wildlife protection ($w=1$), then $S = X$ and $dS/dt = rS(1-S)$. In the same way, with no protection ($w=0$) $S = Y$ and $dS/dt = rS(1-S) - h$. Throughout the analysis it is assumed that $0 < w < 1$.

In absence of man, $h = 0$, Figure 1 illustrates the isoclines of *(1)* and *(2)*. This figure is quite similar to the graphical demonstration of a two-patch density-dependent system in Sanchirico and Wilen [25]. Here, the marginal migration rates are below the maximum specific growth rate so that $1 - zw/r > 0$ and $1 - z(1-w)/r > 0$. See also Skonhoft and Armstrong [27]. This makes sense because a system with a migration exceeding the intrinsic growth is likely to fail in sustaining an ecological equilibrium with positive biomass within each patch. The X-isocline is a strictly convex function of X and runs through the point (1,1). Above the isocline, the natural growth and dispersion from the outer area exceed the dispersion out of the reserve so that $dX/dt > 0$. The opposite occurs below the isocline. The *Y*-isocline is a strictly concave function of *X* and runs through the point (*1*,*1*). Below the isocline, dY/dt is positive, whereas above, dY/dt is negative.

Figure 1 about here

In absence of man and migration below the intrinsic growth, it will therefore be a unique equilibrium with stock densities equal to one. Hence, the aggregate stock equals one in equilibrium. It can be demonstrated that the equilibrium is stable[6]. The feasible region for an interior solution of the system is found in the area closed by the isoclines and the axes. The size of this region depends on the biological parameters of the model. If the moving rate *z* approaches zero, i.e. a system of closed and independent patches, the individual stocks collapse to zero or the carrying capacity of its area. If the moving rate increases so that zw/r (or $z(1-w)/r$) approaches one, the feasible region reduces and collapses to a lens with intersection at (*a*,0) (or (0,*b*)) and (1,1), where $a = 1 - z(1-w)/r$ (and $b = 1 - zw/r$).

Throughout this analysis it is assumed that the patches are interdependent, i.e. *z* is positive. Introducing human activity as a fixed positive harvesting rate in this system shifts the *Y*-isocline in Figure 1 down, i.e. human activity reduces the density in the outer area for a given stock density in the game reserve. Consequently, due to a relative dense population in the protected area, wildlife disperses to the outer area, which causes a decline in *X*. This illustrates that harvesting in the outer area spells over to the protected area. The system settles in a new stable equilibrium where both stock levels are smaller than their respective carrying capacities and $Y < X$. Throughout the remaining analysis it is assumed that the system is in ecological equilibrium ($dX / dt = dY / dt = 0$).

3. The economy

The ecological steady state above was established for a given harvesting rate. However, the harvesting activity is determined by economic considerations, which are outlined in this section. Before we move to the economic part, it is convenient to establish the different ways in which land is utilized in this model.

The local people have legal rights to utilize the outer area in agricultural production and wildlife hunting. However, for presumed conservation purposes, the State may expand the protected area. This can only take place by implementing parts of the outer land into the park area. There are two ways in which the State may accomplish this, and these are related to the type of land as discussed in section 1. First, if present, the State can protect non-cultivated land. For the local people living in the outer area, this policy represents limited user rights to wildlife, but no restriction on the rights to exploit land already cultivated for agricultural use. Technically, this will be the case where the constraint on agricultural land is non-binding. Second, in marginal areas, the State must expropriate cultivated land in order to expand the protected area. For the local people, this procedure restricts their user rights to agricultural land as well as their user rights to wildlife. This will be the case when the constraint on agricultural land use is binding. The two scenarios of protected area expansion will be analysed in section 4.1 and 4.2, respectively.

The next step is to present a formal model of the agricultural and hunting decision of the local people. Throughout the analysis the local people are considered a homogenous group of peasants and, in line with traditional reasoning, it is assumed that the elders are in charge of the group's activities (Marks [19]). Agricultural production, which is interpreted as crop production, is a function of labour E_A and land L as $A(E_A, L)$. As mentioned in section 2, land is homogeneous as habitat for wildlife. It is therefore convenient to consider land as homogeneous for agricultural uses as well. This means that additional land is equally suitable in agriculture as previously exploited land. Then, proportional increases in labour effort and land use must cause output to increase by the same proportion. Consequently, the average returns to land A/L and labour A/E_A are left unchanged. The agricultural production function is therefore characterised by constant returns to scale and specified as a Cobb-Douglas type as follows (Hayami and Ruttan [14]).

(3) $$A(E_A, L) = \mu E_A{}^{\alpha} L^{1-\alpha},$$

Here, $\mu > 0$ is a technology parameter and $0 < \alpha < 1$ is the output elasticity of labour. Because of its homogeneity, diminishing return to land is not caused by taking inferior land into production, but by reduced labour effort per unit of land[7]. The total area available for agricultural production is given by the size of the outer area $(1-w)$. The constraint on land use is therefore given by

(4) $$L \leq (1-w)$$

As in Bulte and Horan [6], investment costs on land, for instance related to clearing and fencing, are ignored in this analysis. The only agricultural cost of consideration is related to damage caused by wildlife roaming on agricultural land. The nuisance stream per unit of land is equal to cY, with $c > 0$ and fixed[8]. Consequently, the total damage of the wildlife roaming on agricultural land is cLY. c is interpreted as the marginal damage per animal. All else equal, more agricultural land means more nuisances.

The number of animals harvested H is specified as a function of labour effort E_h, stock density Y, and the size of the outer area $(1-w)$, as $H = H(E_h, Y, 1-w)$. Because land is considered homogenous for agricultural uses in the sense that proportional increases in labour and land use cause output to increase by the same proportion, it is also reasonable to assume constant return to scale in hunting with respect to labour and land. When assuming that H is linear in Y, the wildlife offtake is specified as

$$(5) \qquad H = qE_h^{\,\beta}(1-w)^{1-\beta}Y$$

Here, $q > 0$ is a productivity parameter and $0 < \beta < 1$ is the output elasticity of labour. The marginal return to land is positive because additional areas are open for hunting as the outer area expands. Diminishing return to land is caused by reduced labour effort per unit of land. To translate the offtake into change in the wildlife density in the outer area in *(2)*, we divide H with the size of this area, so that $h = H/(1-w)$ is the hunting rate[9].

The endowment of labour is normalized to one and, hence, the constraint on labour use reads[10]

$$(6) \qquad E_h + E_A \leq 1,$$

Throughout the analysis it is assumed that the constraint is binding. A trade-off between wildlife hunting and agricultural production is present in that the opportunity cost of wildlife harvesting equals the foregone return from agricultural production (and vice versa).

When inserting for the effort constraint *(6)* into the production function in *(3)*, the net benefit function of the local people yields[11]

$$(7) \qquad \pi = P_h E_h{}^{\beta}(1-w)^{1-\beta} Y + P_A \mu (1-E_h)^{\alpha} L^{1-\alpha} - P_A cLY \,,$$

where P_h and P_A denote the price of game meat and agricultural output, respectively. A simplifying assumption is that prices are fixed, meaning that the local people are well integrated with markets for agricultural output and game meat. This is in line with Skonhoft and Solstad [28]. Whether local people in reality are well integrated with such markets or not depends on the level of transaction costs: Using evidence from Serengeti in Tanzania, Barnett [1] and Campbell et al. [8] claim that the local people sell game meat at both local and external markets. However, Barnett [1] gives a more diverse picture of the market setting for game meat when comparing several East- and Southern African countries. Accordingly, market setting varies across products and geographical areas. See also Muller and Albers [21] for an analysis of the role of the market setting. However, in order to avoid complexity, prices are fixed in the present model.

As mentioned, the local people have user rights to land and wildlife. This means that they are not granted titles to these resources and, consequently, they face a continuing risk of the State withdrawing their user rights through an expansion of the protected area. The local people have therefore few, if any, incentives to base their wildlife harvesting on long-term considerations[12]. Further, the local people are unable to control the wildlife stock due to migration between protected land, where wildlife is controlled by the State, and the outer area. Because of these reasons, they do not take the stock of wildlife into account when deciding upon their effort use. Technically, this is captured by assuming that the local peasants treat the stock density Y as exogenous, which is in accordance with one of Smith's models [29]. See also Skonhoft and Solstad [28]. The local people choose the hunting effort E_h and cultivated land L to maximize *(7)*, given the constraint on land use in *(4)*. The Lagrange function reads $V = P_h q E_h{}^{\beta}(1-w)^{1-\beta}Y + P_A\mu(1-E_h)^{\alpha}L^{1-\alpha} - P_A cLY - \lambda(L-(1-w))$, where λ is the shadow price of land. Equations *(8)*-*(10)* yield the first order conditions for maximum when an interior solution for hunting effort is supposed to be present.

$$P_h q\beta E_h{}^{\beta-1}(1-w)^{1-\beta}Y = P_A\mu\alpha(1-E_h)^{\alpha-1}L^{1-\alpha} \tag{8}$$

$$P_A\mu(1-\alpha)(1-E_h)^{\alpha}L^{-\alpha} = P_A cY + \lambda \tag{9}$$

$$\lambda \geq 0;\ \lambda = 0 \text{ if } L < (1-w) \tag{10}$$

Equation *(8)* shows that the optimal hunting effort is determined by equality between the marginal product of hunting and the marginal product of labour effort in agricultural production. The decision rule in equation *(9)* states that the local people will convert land in the outer area to agricultural use until the value of the marginal product of land in crop production equals the marginal cost. The marginal cost consists of the value of the marginal damage per unit cultivated land and the shadow value of land. This value equals zero when the constraint on land use is non-binding, while it is positive for a binding constraint (see *(10)*).

The economic equilibrium condition in *(9)* is illustrated graphically in Figure 2. Here, the marginal benefit and costs of land cultivation are measured along the vertical axis. Consider the case of intersection between the marginal cost curve and the marginal benefit curve, which results in $L = L^I < (1 - w)$. This means that the local people choose not to utilize the whole outer area for cultivation and, hence, λ = 0. However, a positive shift in agricultural productivity μ and/or a downward shift in the marginal crop damage caused by a lower c or Y, increase the demand for cultivated land. In Figure 2, this is illustrated by an upward shift in the marginal benefit curve caused by a higher μ. For a given land use at L^I, the marginal benefit of cultivated land exceeds the marginal crop damage by the positive shadow value of land. The local people respond by converting additional land to agricultural production. In the new equilibrium, λ remains positive if the local people utilize the whole outer area for agricultural production, $L = (1 - w)$, reflecting that land is a scarce factor. This will be the case if μ is 'high', while c and Y are 'low'. In addition, an increase in the size of the protected area w shifts the vertical curve denoting the size of the outer area to the left and increases the shadow value of land.

Figure 2 about here

Equation *(8)*-*(10)* together with *(1)* and *(2)* (with $dX/dt = dY/dt = 0$) determine the optimal hunting effort, optimal use of agricultural land and the aggregate stock in ecological equilibrium. The following section describes the two scenarios of a non-binding and a binding constraint on land use.

4. The impact of protected areas on wildlife conservation and local welfare

Above we established the first order conditions maximizing the local people's benefit from wildlife harvesting and agricultural production. In addition, we studied the conditions under which the system settles in a solution where the constraint on land use is binding. The next step is to investigate the impact on wildlife conservation and the welfare of the local people of protected areas. It turns out that the effects are strictly dependent on whether the state gazettes non-cultivated land or expropriates cultivated land, i.e. whether the constraint on land use is non-binding or binding. Section 4.1 considers the case of a non-binding constraint on land use, while the constraint is binding in section 4.2.

4.1 The constraint on land use is non-binding

Assume that the protected area is relatively small, so that land is not a scarce factor in the outer area. Then, the local people settle with an interior solution for cultivated land, $L < (1-w)$, where the marginal return from land equals the marginal damage in *(9)* and $\lambda = 0$. Combining *(8)* and *(9)* (with $\lambda = 0$) and solving for Y gives

$$(11) \qquad Y = \mu\left[P_A\alpha / P_h\beta q\right]^{\alpha}\left[(1-\alpha)/c\right]^{1-\alpha}\left[E_h/(1-w)\right]^{(1-\beta)/\alpha}$$

Equation *(11)* and the ecological equilibrium in *(1)* and *(2)* (with $dX/dt = dY/dt = 0$) determine the optimal hunting effort and equilibrium stock densities. The aggregate stock follows from $dS/dt = 0$. The amount of cultivated land L is determined through the input proportion derived from equation *(9)*.

The economic and ecological effects of an expansion of the protected area is found by taking the total differential of *(11)* and *(1)* and *(2)* (with $dX / dt = dY / dt = 0$) (for details, see Appendix 2). With a non-binding constraint on land use, the state gazettes non-cultivated land when expanding the protected area. This means that more habitat protection displaces the local people from pre-hunting areas without restricting their rights to utilize land in agricultural production. Alternatively, because land is homogeneous and investment cost in land is neglected, this can also be interpreted as a situation where the state gazettes cultivated land. Then, without a cost, the local people move their agricultural production to pre-non-cultivated areas. See also section 5.

In any case, an expansion of the protected area has an unclear effect on the hunting effort. Still, this policy unambiguously increases the stock density in the outer area. This gives more dispersal into the protected area and leads to a more dense population here. Because of increased stock densities, there must be a positive effect on the aggregate stock of gazetting non-cultivated land for wildlife protection. The conclusion is therefore that more protection gives more wildlife even if the local people increase their hunting effort.

The next step is to investigate how this intervention affects the economic conditions of the local people. This is done by taking the differential of *(7)* with respect to *w*, when accounting for the effect working through a changing stock density (see Appendix, section 2). It turns out that the impact on the welfare of the local people is ambiguous. First, and quite in line with the findings of Sanchirico and Wilen [25] for a marine reserve, income from hunting increases if increased wildlife density compensates for the foregone harvest along the protected area expansion. What is new compared to marine reserve creation is that a more dense wildlife population imposes increased damage to agricultural crops per unit land. If the latter effect is strong, then gazetting non-cultivated land for habitat protection will promote wildlife conservation at the expense of human welfare even if income from hunting increases. See also Table 1 in section 4.2.

4.2 The constraint on land use is binding

Assume that land is a scarce factor to the local people living in the outer area. This is the case if, relatively speaking, the protected area is widespread, the agricultural productivity is high, and/or the marginal wildlife-induced damage to crops is low. In such a scenario, the local people settle in a corner solution for cultivated land, i.e. $L = (1-w)$ and $\lambda > 0$ from *(10)*. Hence, the marginal return on land cultivation exceeds the marginal damage in *(9)*. See also Figure 2. Inserting $L = (1-w)$ in *(8)* gives

$$(12) \qquad P_h \beta q E_h^{\beta-1}(1-w)^{1-\beta} Y = P_A \mu \alpha (1-E_h)^{\alpha-1}(1-w)^{1-\alpha}$$

Equation *(12)* states that the local people will divert effort to hunting until the marginal benefit of hunting equals the marginal cost. The marginal cost reflects the alternative cost of hunting, namely the foregone return on agricultural production.

The economic equilibrium for a given wildlife density in the outer area is illustrated in Figure 3. Here, the marginal benefit from hunting (MBH) is measured along the left-hand vertical axis, while the marginal benefit from agricultural production (MBA) is measured along the right-hand axis. The optimal hunting effort is determined by the intersection between the two curves.

Figure 3 about here

Equation *(12)* shows that an expansion of the protected area, i.e. an increase in w, has a direct negative effect on the marginal return on labour in agriculture. This is because the State must expropriate cultivated land in order to expand the protected area and this is new compared to the non-binding case. Consequently, the MBA curve in Figure 3 shifts down, which works in the direction of increased hunting effort. However, restricted hunting rights reduce the marginal return on hunting, which shifts the MBH curve down. This leads the local people to direct less effort towards hunting. The total effect on hunting effort is therefore unclear. If restricted hunting rights affect the local people less than reduced cultivated land, i.e. $\left|\partial^2 H / \partial E_h \partial w\right| < \left|\partial^2 A / \partial(1 - E_h)\partial w\right|$, they will reply to habitat protection by directing more effort to hunting[13]. This is illustrated in Figure 3 by a stronger downward shift in the MBA curve.

If the harvesting effort changes, however, both the wildlife densities and the aggregate stock will change, since they all depend on E_h. The first order condition in *(12)* and the ecological equilibrium in *(1)* and *(2)* (with $dX / dt = dY / dt = 0$), determine the optimal hunting effort and the stock densities. Again, the aggregate stock follows from $dS / dt = 0$. Differentiation of these equations with respect to w gives the impact of a protected area expansion (for details, see Appendix). In contrast to section 4.1, it turns out that the effect on wildlife conservation is ambiguous.

The mechanism works as follows. Consider first the direct effect. Because more animals are protected from hunting for a given hunting effort, the aggregate stock S increases. Second, we have the indirect effect working through the hunting decision of the local people. As discussed above, restricted user rights to wildlife reduce the marginal return from labour in hunting, while restricted user rights in agriculture reduce the marginal return from labour in crop production. These have opposite effects on the hunting effort. As argued, if the local people respond less to the closed hunting ground than the loss of cultivated land, they will divert more labour effort towards wildlife exploitation. This will be the case in areas where the local people rely heavily on agriculture as a land use so that expropriation of cultivated land represents a considerable income loss. In this case, the indirect effect on wildlife conservation implies less wildlife in the outer area and a smaller aggregate stock. The total effect on wildlife conservation is therefore unclear. Contrary to the non-binding scenario, this demonstrates that protected areas which restrict the user rights to wildlife and cultivated land may reduce the degree of wildlife conservation. This paradoxical result occurs because the constraint on land use in agriculture is binding, meaning that there is an alternative use of the protected land in agricultural production.

The final part of this analysis is to investigate how expropriation of cultivated land affects the economic conditions of the local people living with wildlife. Again, differentiation of *(7)* with respect to w, when taking into account the effect working via a changing wildlife stock, gives the effect on local income in optimum. There are three possible outcomes regarding wildlife conservation and local welfare, and these are summarised in the second column of Table 1. Assume first that an expansion of the protected area fails and results in a smaller degree of wildlife conservation. As reported in the table, this must lead to poorer economic conditions for the local people[14]. The model therefore predicts that where protected areas have failed in promoting wildlife conservation, they have also caused a degradation of local welfare.

Table 1 about here

Second, assume that an expansion of the protected area promotes wildlife conservation. As shown in Table 1, the resulting effect on local welfare is ambiguous and dependent on whether the marginal return on hunting with respect to the wildlife stock $(1\text{-}w)Y$ is above or below the marginal agricultural damage with respect to $(1\text{-}w)Y$ and the size of the moving rate of wildlife. See *(A7)* in Appendix. If the marginal damage exceeds the marginal return on hunting, i.e. P_A and c are 'high' and P_h is 'low', then protected areas resulting in a higher degree of wildlife conservation will unambiguously reduce the welfare of the local people. See the fourth column of Table 1. If, on the other hand, the marginal return on hunting exceeds the marginal damage (i.e. P_h is 'high' and P_A and c are 'low'), then protected areas will promote both wildlife conservation and local welfare if increased hunting income due to an increased wildlife stock in the outer area, compensates for the foregone return from pre-agricultural land. This will be the case if the agricultural productivity is 'low'. See the fifth column of Table 1.

5. Discussion and concluding remarks

Establishing national parks and other types of protected areas have been the traditional approach to natural resource conservation in Africa. However, this practise has during the past decade been subject for debate: While, e.g., Martin [20] argues that small budgets and funds causes protected areas to fail in preserving wildlife, Bruner et al. [5] claim that protected areas work well.

This debate is the starting point of the present paper. In line with the findings of Bruner et al. [5] the ecological model implies that, in presence of hunting in the outer area, the wildlife density in the protected area is higher compared with the outer area. In contrast to Martin

[20], however, it is assumed that anti-poaching law enforcement succeeds in eliminating illegal hunting in the protected area. Still, this demonstrates that protected areas may cause wildlife degradation.

The ecosystem of consideration in this paper is of fixed size and consists of two sub-areas – the protected area and the outer area – over which the wildlife stock disperses. The outer area is settled by humans who utilize this area for wildlife hunting and agricultural production. The local people have user rights to wildlife and land for cultivation in the outer area, but they do not have the property rights. Related to the land use in the outer area, this paper distinguishes between two ways of gazetting land. First, the state gazettes non-cultivated land. This policy restricts the local people's user rights to wildlife by withdrawing former hunting grounds without interfering with their rights to cultivate land. Technically, this is the case where the constraint on land use is non-binding. Second, the state expropriates cultivated land, a policy which restricts the local people's user rights to both wildlife and land for cultivation. In this scenario, the constraint on land use is binding.

The main point of the analysis is to find out under which conditions protected areas may fail in conserving wildlife. In addition, the analysis focuses on the economic impact of protected areas by investigating the effect on local welfare. It is shown that the actual outcome of habitat protection depends critically on whether the constraint on land use is binding. Only when the constraint is non-binding will protected areas with certainty increase the wildlife stock. This scenario is quite similar to a marine reserve creation with no alternative use of the marine habitat. However, in contrast to marine reserves, the impact on the welfare of the local people is unclear, even if increased wildlife density compensates for the foregone harvest on the pre-hunting grounds: Then a double payoff occurs only if damage imposed by wildlife to agriculture is small.

Protected areas work quite differently from marine reserves when the constraint on land use is binding and the State expropriates cultivated land for wildlife protection. The discrepancy stems from the alternative use of protected land as land for agricultural production. The model demonstrates that an expansion of the protected area may cause a degradation of wildlife if the productivity of labour in agriculture is more sensitive to restricted access to land than the productivity of labour in hunting. If this is the case, then the local people will compensate themselves by devoting more time on hunting. In the opposite case, the local people respond to land expropriation by spending less time hunting and, consequently, the wildlife stock increases. A double payoff will then emerge if wildlife-induced damage to agricultural crops is small and increased wildlife dispersal from the protected area compensates for the foregone wildlife harvest and agricultural production along the protected area expansion.

Hence, with respect to wildlife conservation, this model predicts that protected areas work well in areas where uncultivated land is gazetted, while the success of expropriating cultivated land is conditioned on how sensitive local people are to changes in the size of the area available for cultivation. A more promising way of promoting wildlife conservation than expropriating cultivated land may be to encourage improved productivity in agriculture (increased μ, see Appendix section 2). The impact on local welfare is, however, still unclear. But if the level of agricultural damage per animal is ‘small’, then improved agricultural productivity will promote both wildlife conservation and local welfare. This kind of support is often found in existing ICDPs (see section 1).

It is important to note that this model simplifies the interaction between the wildlife population dynamics and human activities. In the ecological part of the model, the quality of land as habitat for wildlife is considered constant and independent of the agricultural use in the outer area. In reality, however, unexploited areas may generate more wildlife than cultivated land. Hence, the analysis overlooks one plausible positive effect on wildlife conservation as protected areas displace agricultural activities in the wildlife habitat.

Another simplification made is to assume that land conversion is costless. In the non-binding scenario this assumption may be interpreted as if the State offers the local community full compensation for any costs of moving the agricultural production to pre non-cultivated areas. The conservation effect of expropriating pre-cultivated land will then be identical to that of gazetting non-cultivated land. The case of a binding constraint on land use may, on the other hand, be considered as a situation where the local people receive no compensation for the loss of agricultural land and where high conversion costs therefore prevent the local people from moving to pre non-cultivated areas.

Figures

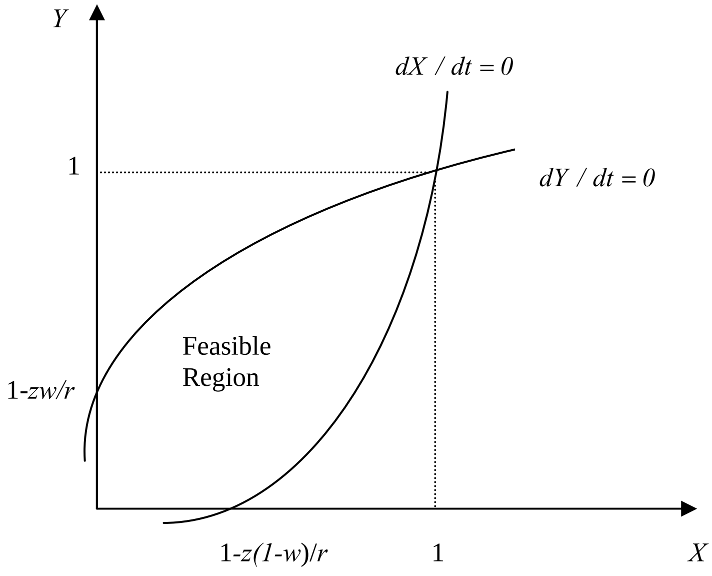

Figure 1: Ecological equilibrium in absence of man.

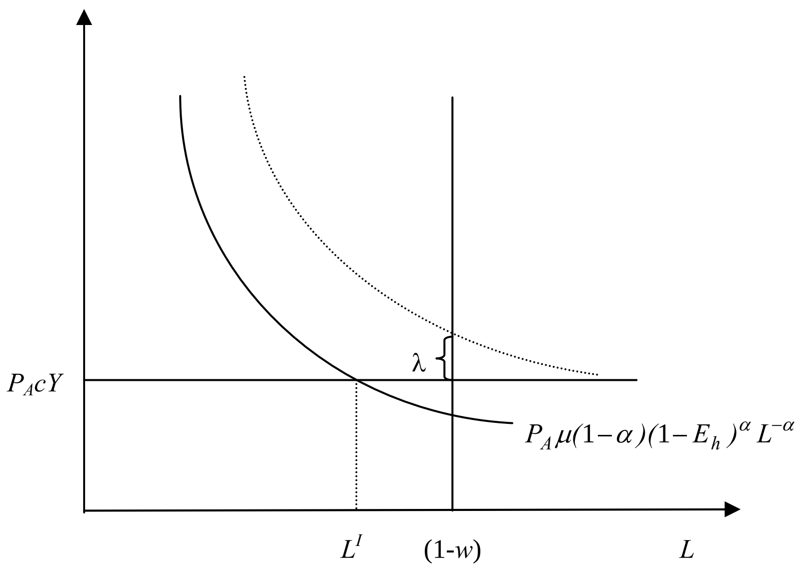

Figure 2: The maximum condition for the amount of cultivated land L. Y and E_h are fixed.

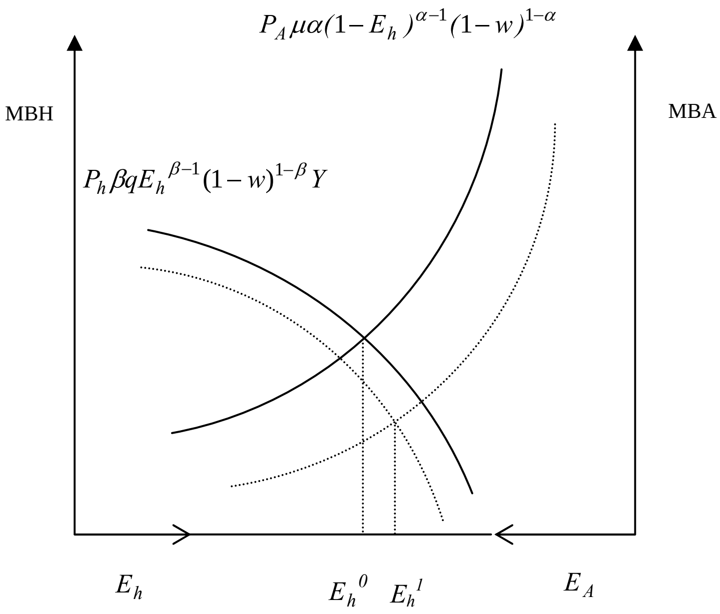

Figure 3: The maximum condition for hunting effort E_h. The constraint on land is binding. Dashed curves represent increased habitat protection (w)**,** Y is fixed.

Tables

Table 1: The welfare effect of an increase in *w* in equilibrium.

	Non-binding constraint on land use			Binding constraint on land use*	
S	+		÷	+	
π	÷** P_A and c high and P_h low	+** P_A and c low, and P_h high,	÷	÷** P_A and c high and P_h low	+** P_A, c and μ low, and P_h high,

* The welfare effect is conditioned by the impact on wildlife conservation.

** Here, it is assumed that the wildlife stock in the outer area increases, $d(1-w)Y / dw > 0$.

Appendix

1. The ecological system

The shapes of the X-isocline and Y-isocline in Figure 1 are found by taking the differential of *(1)* (with $dX/dt = 0$) and *(2)* (with $dY/dt = 0$), respectively, with respect to X and Y, and are given as $dY/dX\big|_{dX/dt=0} = -[r(1-2X) - z(1-w)]/z(1-w)$ and $dY/dX\big|_{dY/dt=0} = -zw/[r(1-2Y) - zw]$ in the (X,Y)-plane. The second order differentials show that the X-isocline is convex, while the Y-isocline is concave. Hence, an interior solution of the ecological system ($X > 0$ and $Y > 0$) requires the X-isocline to intersect the Y-isocline from below. That is, $[r(1-2X) - z(1-w)] < 0$ and $[r(1-2Y) - zw] < 0$. These signs are useful for the comparative static analyses below.

Consider the differentiation of the ecological system in case of exogenous changes in the size of the protected area w and the hunting effort E_h. The total differential of the ecological equilibrium $dX/dt = dY/dt = 0$ in *(1)* and *(2)* when $h = q(E_h/(1-w))^{\beta} Y$ yields

$$\begin{bmatrix} r(1-2X) - z(1-w) & z(1-w) \\ zw & r(1-2Y) - zw - q(E_h/(1-w))^{\beta} \end{bmatrix} \begin{bmatrix} dX \\ dY \end{bmatrix}$$

$$(A1) \qquad = \begin{bmatrix} z(Y-X) \\ z(Y-X) + \beta q(E_h/(1-w))^{\beta-1} Y/(1-w) \end{bmatrix} dw$$

$$+ \begin{bmatrix} 0 \\ \beta q(E_h/(1-w))^{\beta-1} Y/(1-w) \end{bmatrix} dE_h + \begin{bmatrix} 0 \\ -(E_h/(1-w))^{\beta} Y \end{bmatrix} dq$$

The determinant $D = [r(1-2X) - z(1-w)][r(1-2Y) - zw - q(E_h/(1-w))^{\beta}] - z^2 w(1-w)$ is positive from the condition of ecological stability.

2. Non-binding constraint on land use

Differentiation of *(11)* gives

$$(A2)\quad dE_h = 1/\left\{\mu[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha-1}(1-\beta)/\alpha(1-w)\right\}dY$$

$$-E_h/(1-w)dw-(1/\gamma)[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha}d\mu$$

$$-(\alpha\mu/P_A\gamma)[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha}dP_A$$

$$+((1-\alpha)\mu/c\gamma)[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha}dc$$

$$+(\mu/P_h\gamma)[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha}dP_h$$

$$+(\mu/q\gamma)[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha}dq$$

where $\gamma = \mu[\alpha P_A/\beta P_h q]^{\alpha}[(1-\alpha)/c]^{1-\alpha}[E_h/(1-w)]^{(1-\beta)/\alpha-1}(1-\beta)/\alpha(1-w) > 0$. Define η_μ as the term multiplied by $d\mu$, η_{P_A} as the term multiplied by dP_A etc. in *(A2)*. Then, when inserting *(A2)* in *(A1)*, the comparative static results yield *(A3)*

$$\begin{bmatrix} r(1-2X)-z(1-w) & z(1-w) \\ zw & [r(1-2Y)-zw-q(E_h/(1-w))^{\beta}-\beta q(E_h/(1-w))^{\beta-1}Y/\gamma(1-w)] \end{bmatrix}\begin{bmatrix} dX \\ dY \end{bmatrix}$$

$$=\begin{bmatrix} z(Y-X) \\ z(Y-X) \end{bmatrix}dw-\begin{bmatrix} 0 \\ \eta_\mu q\beta(E_h/(1-w))^{\beta-1}Y/(1-w) \end{bmatrix}d\mu+\begin{bmatrix} 0 \\ \eta_{P_A} q\beta(E_h/(1-w))^{\beta-1}Y/(1-w) \end{bmatrix}dP_A$$

$$+\begin{bmatrix} 0 \\ \eta_c q\beta(E_h/(1-w))^{\beta-1}Y/(1-w) \end{bmatrix}dc+\begin{bmatrix} 0 \\ \eta_{P_h} q\beta(E_h/(1-w))^{\beta-1}Y/(1-w) \end{bmatrix}dP_h$$

$$+\begin{bmatrix} 0 \\ -(E_h/(1-w))^{\beta}Y+\eta_q q\beta(E_h/(1-w))^{\beta-1}Y/(1-w) \end{bmatrix}dq$$

The determinant

$$\left[r(1-2X)-z(1-w)\right]\left[r(1-2Y)-zw-q(E_h/(1-w))^{\beta}-\beta q(E_h/(1-w))^{\beta-1}Y/\gamma(1-w)\right]-z^2w(1-w)$$

is positive from the condition of ecological stability. The corresponding change in the aggregate stock density equals $dS = wdX + (1-w)dY - (Y-X)dw$, while the impact on E_h is given in *(A2)*.

The impact on local welfare of an expansion of the protected area is found by differentiating *(7)* with respect to *w*, making use of the first order conditions in *(8)* and *(9)* (with λ=0), and rearrange:

$$(A4) \qquad \partial\pi/\partial w = P_h q(E_h/(1-w))^{\beta}(1-w)^{-\beta}\left[(1-w)dY/dw-(1-\beta)Y\right]-P_A cLdY/dw$$

where *dY/dw* is derived from differentiation of *(A3)*. The first term $(1-w)dY/dw$ in the bracket reflects that income from hunting increases due to increased stock density in the outer area, while the second term $-(1-\beta)Y$ reflects reduced income from hunting due to the foregone return from the pre-hunting ground. The final term $-P_A cLdY/dw$ implies reduced income due to increased crop damage per unit agricultural land.

3. Binding constraint on land use

The final step is to investigate the impact of an expansion of the protected area when the constraint on land use is binding. Differentiation of *(12)* and rearranging yields

$$(A5)\quad \begin{aligned} &-\left[\alpha(1-\alpha)P_A\mu(1-E_h)^{\alpha-2}(1-w)^{1-\alpha}+\beta(1-\beta)P_hqE_h{}^{\beta-2}(1-w)^{1-\beta}Y\right]dE_h \\ &+\beta P_hqE_h{}^{\beta-1}(1-w)^{1-\beta}dY=\alpha(\alpha-\beta)P_A\mu(1-E_h)^{\alpha-1}(1-w)^{\beta-\alpha-1}dw \\ &-\beta qE_h{}^{\beta-1}(1-w)^{1-\beta}YdP_h-\beta P_hE_h{}^{\beta-1}(1-w)^{1-\beta}Ydq \\ &+\alpha\mu(1-E_h)^{\alpha-1}(1-w)^{1-\alpha}dP_A+\alpha P_A(1-E_h)^{\alpha-1}(1-w)^{1-\alpha}d\mu \end{aligned}$$

From *(A1)* dY can be expressed as a function of dE_h, dw and dq. Inserting this function into *(A5)* gives dE_h as a function of dw, dP_h, dq, dP_A and $d\mu$. When inserting for dY and dX from *(A1)* into $dS = wdX+(1-w)dY-(Y-X)dw$, dS is expressed as a function of dE_h, dw, dP_h, dq, dP_A and $d\mu$. Together, these expressions give to equations in two endogenous variables, dS and dE_h, and five exogenous, dw, dP_h, dq, dP_A and $d\mu$:

$$(A6)\quad \begin{aligned} &\begin{bmatrix} 0 & \delta \\ 1 & \sigma \end{bmatrix}\begin{bmatrix} dS \\ dE_h \end{bmatrix}=\begin{bmatrix} \tau \\ \theta \end{bmatrix}dw+\begin{bmatrix} -\beta q(E_h/(1-w))^{\beta-1}Y \\ 0 \end{bmatrix}dP_h \\ &+\begin{bmatrix} \beta P_hq(E_h/(1-w))^{2\beta-1}Y\left[r(1-2X)-z(1-w)\right]/D \\ (1-w)(E_h/(1-w))^{\beta}Y\left[zw-\left[r(1-2X)-z(1-w)\right]\right]/D \end{bmatrix}dq \\ &+\begin{bmatrix} \alpha\mu(1-E_h)^{\alpha-1}(1-w)^{1-\alpha} \\ 0 \end{bmatrix}dP_A+\begin{bmatrix} \alpha P_A(1-E_h)^{\alpha-1}(1-w)^{1-\alpha} \\ 0 \end{bmatrix}\mu \end{aligned}$$

Here the first row refers to the economic part of the model, while the second row refers to the ecological part. The sign of

$\delta=-\alpha(1-\alpha)P_A\mu(1-E_h)^{\alpha-2}(1-w)^{1-\alpha}-\beta(1-\beta)P_hqE_h{}^{\beta-2}(1-w)^{1-\beta}Y$

$+\beta P_hqE_h{}^{\beta-1}(1-w)^{1-\beta}\left[r(1-2X)-z(1-w)\right]q(E_h/(1-w))^{\beta-1}/D$ is negative and, hence, the determinant is positive. The sign of $\sigma=-\beta q(E_h/(1-w))^{\beta-1}Y\left[r(1-2X)-z(1-w)-zw\right]/D$

is positive, while the signs of

$$\theta = (X - Y) - \left[z(1-w)(X-Y) - \beta q(E_h/(1-w))^{\beta} Y\right]\left[r(1-2X) - z(1-w) - zw\right]/D$$

$$- zw(X-Y)\left[r(1-2Y) - zw - z(1-w) - q(E_h/(1-w))^{\beta}\right]/D$$ and

$$\tau = \alpha(\alpha-\beta)P_A\mu(1-E_h)^{\alpha-1}(1-w)^{\beta-\alpha-1}$$

$$- \beta P_h q E_h^{\ \beta-1}(1-w)^{1-\beta}\left\{\left[r(1-2X) - z(1-w)\right]\left[z(Y-X) + \beta q(E_h((1-w))^{\beta} Y/(1-w)\right] - z^2 w(Y-X)\right\}/D$$

are unclear.

Again, the welfare effect is derived from the differentiation of *(7)* with respect to *w*, using the first order condition in *(12)*, and rearrange:

$$\partial\pi/\partial w = \left[P_h q E_h^{\ \beta}(1-w)^{-\beta} - P_A c\right]\left[(1-w)dY/dw - Y\right] - P_A\mu(1-\alpha)(1-E_h)^{\alpha}(1-w)^{-\alpha} \qquad (A7)$$

Solving *(A5)* for *dY/dw* yields

$$dY/dw = \alpha(\alpha-\beta)P_A\mu(1-E_h)^{\alpha-1}(1-w)^{\beta-\alpha-1}/\left[\beta P_h q E_h^{\ \beta-1}(1-w)^{1-\beta}\right] +$$
$$\left\{\left[\alpha(1-\alpha)P_A\mu(1-E_h)^{\alpha-2}(1-w)^{1-\alpha} + \beta(1-\beta)P_h q E_h^{\ \beta-2}(1-w)^{1-\beta} Y\right]/\left[\beta P_h q E_h^{\ \beta-1}(1-w)^{1-\beta}\right]\right\} dE_h/dw$$

When inserting for dE_h/dw from *(A6)*, this expression shows the impact of a protected area expansion on the wildlife density in the outer area in equilibrium.

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Notes

[1] When analysing the role of market setting, however, Muller and Albers [21] demonstrate that the conservation-effect of payments may be negative in case of a missing market for extracted resources.

[2] In a state property regime individuals or groups may be allowed to make use of the natural resources without having any property rights. Bromley [4] defines this as usufruct rights.

[3] Muller and Albers [21] analyses the likelihood of success of different policies of conservation of terrestrial species in protected areas under different assumptions about the market setting. However, they do not consider the impact of altering the size of the protected area.

[4] Incompatibility also implies that the rate of migration is independent on the type of territory animals traverse.

[5] The moving rate may also be related to breeding. For instance, animals with slow growing non-precocial young are obliged to stay within a small area to breed. This is the case for carnivores like lions and hyenas. In contrast, ungulates with precocial young do not need to stay in one place because the young can follow the mother within an hour or so of birth ([9]).

[6] The stability conditions read $\partial f(1,1)/\partial X + \partial g(1,1)/\partial Y = -(2r+z) < 0$ and $(\partial f(1,1)/\partial X)(\partial g(1,1)/\partial Y) - (\partial f(1,1)/\partial Y)(\partial g(1,1)/\partial X) = r(r+z) > 0$, where $f(X,Y) = rX(1-X) + z(1-w)(Y-X)$ and $g(X,Y) = rY(1-Y) + zw(X-Y)$.

[7] For linear homogeneous or constant return to scale production functions, the marginal products are independent of scale and depend only on the input proportions.

[8] In reality, the local people can perform damage control through fencing, guard patrols and so forth. In the model this would have worked through a changing *c*. Here, such measures are neglected.

[9] As in Barrett and Arcese [2], Lopez [18], Skonhoft [26], Skonhoft and Solstad [28], and Bulte and van Soest [7], hunting by outsiders and professional gangs is ignored.

[10] No market is assumed to exist for labour. This is representative for many local communities close to remote protected areas where most people own land and rely heavily on income from agricultural production. Campbell et al. [8] give evidence from Serengeti, Tanzania. See Muller and Albers [21] for an analysis of the role of the market setting. In the present model a perfect labour market makes protected areas effective: With a fixed wage rate and no constraint on working hours in employment, a labour market eliminates the interaction between hunting and agriculture in the effort decision.

[11] In accordance with the traditions in the past century, it is assumed that no economic compensation is paid to the local people for the loss of access to land and wildlife (Marks [19], Kiss [16], Swanson and Barbier [31], Wells [33]).

[12] Martin [20] points out how the risk of land expropriation affects landholders. He writes (p. 15): "The influence of the preservationist lobby is a serious disincentive for the landholder contemplating an investment in wildlife as a land use". See also Borrini [3].

[13] As seen in *(A5)* in Appendix, this is the case when $\alpha > \beta$.

[14] Obviously, protection of agricultural land cannot promote local welfare at the expense of wildlife conservation. $d\pi/dw>0$ together with $dS/dw<0$ must imply that the local people were utilizing 'too much' land for agricultural production prior to the expansion of the protected area. In this case, profit-maximization requires the local people to choose an interior solution for cultivated land.