Wildlife conservation policies and incentives to hunt: 
An empirical analysis of illegal hunting in western Serengeti, Tanzania

Anne Borge Johannesen
Department of Economics
Norwegian University of Science and Technology, NTNU
NO-7491 Trondheim
(E-mail: anne.borge@svt.ntnu.no)

Abstract:
This paper estimates functions for effort use in illegal hunting using cross-sectional survey data from households in western Serengeti, Tanzania. One purpose of the analysis is to investigate the impact on illegal hunting of the integrated conservation and development project established in this area, namely the Serengeti Regional Conservation Project (SRCP). We also investigate how the pattern of crop production in agriculture and wildlife-induced damage to crops and domestic animals affect illegal hunting. The empirical results show that the hunting effort is inversely related to participation in SRCP and positively related to the degree of crop production for own consumption. However, the data indicates that the SRCP of today cannot improve the economic conditions in the project villages. Instead, in order to promote both wildlife conservation and human welfare, policymakers should encourage a higher degree of crop production for the market. In addition, assistance and support for preventing wildlife-induced damage have the potential of reducing the hunting pressure and improving the economic conditions in agriculture.

I would like to thank the Norwegian Research Foundation and The European Commission’s BIOECON programme for funding for this paper.
1. Introduction

Protected areas such as national parks and game reserves have long been regarded as crucial in wildlife conservation. The effort to restrict the impact of humans in protected areas has traditionally been concentrated around guard patrols and penalties in order to discourage and prevent encroachment and illegal activities. However, during the past decades, this kind of exclusionary protected area management has been viewed as having failed to preserve wildlife in developing countries (Kiss 1990, Barrett and Arcese 1995, Gibson and Marks 1995). Today there is a growing recognition that the successful management of protected areas depends on the co-operation and support of the local people living with wildlife. In response to this, Integrated Conservation and Development Projects (ICDPs) are frequently adopted in developing countries. These projects aim at changing the incentives of rural inhabitants through benefit-sharing schemes (e.g. direct utilization of wildlife, income transfers from the tourism sector, improved conditions in the agricultural sector etc.), awareness building, and education in wildlife conservation.

ICDPs are based on the assumption that an appropriate set of incentives exists to induce people to change their exploitation practices. However, these projects have recently been the focus of attention because of the untested assumptions behind their strategies. Based on case studies of existing ICDPs, Brandon and Wells (1992) discuss design dilemmas and highlight possible pitfalls regarding their benefit-sharing schemes. They point to several issues that make the design complex, such as defining what uses to allow and how to link the benefit-sharing approach with the conservation objective. Benefit-sharing strategies have also been of focus in the bio-economic literature. For instance, Barrett and Arcese (1998) reveal possible undesirable effects of culling programmes where game meat is distributed to the local people, while Lopez (1998) and Bulte and van Soest (1999) show that improved agricultural productivity may result in increased resource exploitation.

A common feature in the bio-economic models referred to above is that they consider the incompleteness or absence of particular markets. This is a structural characteristic of rural areas in developing countries (de Janvry et al. 1991). Access to markets in remote communities tends to be limited by the large transaction costs associated with geographic isolation and poor infrastructure. Some products are therefore likely to be selected for subsistence use rather than for sale in small towns or other regional markets.
In a household model with no market for game meat, Barrett and Arcese (1998) analyse the wildebeest exploitation in western Serengeti in Tanzania. The existing ICDP in this area is the Serengeti Regional Conservation Project which, among other strategies, distributes game meat to the local people from managed culling operations. Barrett and Arcese investigate the impact of this strategy in a sensitive analysis where the household derives utility from consumption of game meat, agricultural output and leisure. This model implies that increased endowment of game meat through a managed game meat distribution programme reduces the illegal offtake. However, because game meat consumption is a normal good, there is a less than one-for-one trade-off of distributed meat for illegal meat, meaning that the aggregate wildlife offtake increases. Hence, game meat distribution reduces the degree of wildlife conservation.

Another strategy repeatedly proposed in order to promote wildlife conservation is to implement policies which improve the economic conditions in the agricultural sector. For instance, Brown et al. (1993) suggest that improved productivity of labour in agriculture will divert labour away from hunting and thereby reduce the pressure on wildlife. Productivity improvements may be attained through the support of more sophisticated technologies, expansion of irrigation systems, more extensive fertilizer and pesticide use, and easier access to land. Lopez (1998) and Bulte and van Soest (1999) investigate the impact of productivity improvements with varying assumptions about the presence of markets. Bulte and van Soest (1999) assume that there exists a market for agricultural output and demonstrate that the impact on wildlife conservation of increased agricultural productivity is critically dependent on whether there exist markets for game meat and labour. With such markets present, the household solves for the optimal labour use in agriculture and hunting separately. Consequently, improved productivity in the agricultural sector has no effect on wildlife exploitation. With no markets present, they show that the conservation effect of productivity improvements is ambiguous.

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1 This result follows automatically from the assumption that game meat is non-tradable, i.e. the consumption $C$ equals the sum of illegal meat $h$ and distributed meat $M$ as $C = h + M$. Partial derivation of this constraint with respect to $M$ gives $\partial C / \partial M = \partial h / \partial M + 1$. Because game meat is a normal good, i.e. $\partial C / \partial M > 0$, it follows from this equality that $\partial h / \partial M > -1$.

2 The intuition is that when a labour market is present (e.g. formal employment) the household is able to alter the effort use in agriculture by adjusting its labour supply in formal employment, while the effort use in wildlife harvesting is left unchanged, and vice versa.
Lopez (1998) presents a model where the household produces two agricultural commodities, a labour-intensive one and a land-intensive one. He investigates the impact of productivity improvements in agriculture when the household participates in the markets for agricultural commodities and the extracted resource. In the case of fixed endowment of land and no market for labour, he shows that increased productivity of the labour-intensive output is likely to increase the labour demand for farming, and hence reduce the resource extraction. In contrast, increased productivity of the land-intensive output results in increased resource exploitation.

The bio-economic analyses referred to above use theoretical models and numerical analyses in order to identify the impact on resource exploitation of game culling and productivity improvements in agriculture. Moreover, few, if any, empirical regression analyses of the economic incentives to hunt exist in the literature. The present paper adds to the scarce empirical literature by undertaking an analysis of the hunting incentives using cross-sectional survey data from households in western Serengeti. The survey was conducted in the period June to August 2001 among the local communities along the western border of the Serengeti National Park. This area has experienced a rapid growth in human settlement (Campbell and Hofer 1995, Barrett and Arcese 1998) which coincides with a marked increase in the number of poachers arrested in the park (Arcese et al. 1995). Today, Serengeti National Park and its surrounding game reserves contain the world’s largest ungulate herds (Sinclair and Arcese 1995, Barrett and Arcese 1998), but Sinclair (1995, page 24) states that “the illegal killing of the migrant ungulates by poachers is potentially the most serious threat to the Serengeti ecosystem”.

The local people in Serengeti have no legal rights to exploit wildlife, but hunt illegally\(^3\). The purpose of this paper is to examine what may induce the local people to participate in this activity. We investigate the effect of the Serengeti Regional Conservation Project (SRCP) which was implemented in 1993/94 as a response to the increasing pressure from the communities on the western border of Serengeti National Park. The intention of the project is to reconcile wildlife conservation and development for the human populations by providing wildlife benefits to the local people. The main strategy of SRCP is to distribute game meat to

\(^3\) Hunting is not strictly illegal in parts of the western side of Serengeti National Park and persons having a licence are allowed to hunt wildlife. However, none of the respondents in this survey have such a licence and, hence, all hunting reported is illegal.
the project villages (see SRCS 1993, SRCS 1995, Rugumayo 1999). SRCP has also assisted the training of village game scouts and the establishment village wildlife funds (see also section 3.1).

In addition to the impact of SRCP, this paper investigates how the illegal hunting is related to the crop composition in agriculture. Here, we distinguish between cash crops and food crops sold on the market, and food crops produced for own consumption only. This distinction allows us to analyse the impact of access and participation in the market for agricultural crops on illegal hunting. The third contribution of this paper is to investigate how wildlife-induced damage to crops and domestic animals affects illegal hunting.

The rest of the paper is organized as follows. Section 2 presents the theoretical modelling of the hunting decision of the household. The data set is presented in section 3, while the empirical specification and the estimation results are derived in section 4. Finally, section 5 contains a summary and discussion of the main findings in the paper.

2. The theoretical model

The starting point of the theoretical modelling is an ecosystem that serves as a habitat for wildlife and a living area for humans. The local people are involved in two production activities; agricultural crop production and wildlife harvesting. The State or a management authority has the property rights to wildlife and wildlife utilization performed by the local people is illegal. Still, illegal hunting takes place due to lack of anti-poaching law enforcement. There are two basic motives behind hunting. First, the local people hunt to supplement domestic income and game meat consumption. In addition, they hunt to get rid of ‘problem’ animals destroying agricultural crops.

The following investigates the impact on illegal hunting of game meat transfers to the local people from managed culling operations, productivity improvements in agriculture, and policies aimed at reducing the wildlife-induced damage. The theoretical model also captures the effect of income transfers from the tourism sector, a tool which is frequently implemented in existing ICDPs. It is demonstrated that such transfers may provide the household with sufficient money to purchase game meat on the market. It turns out that this affects the impact on illegal hunting of a changing price of game meat.
Assume that the local people constitute a group of \( n \) identical households. Following de Janvry et al. (1991), the representative household diverts labour between agricultural crop production and illegal hunting, so as to maximize the utility it derives from consumption of these goods. The utility function is given by

\[
U^i = U(C^c_i, C^m_i), \quad i = 1, \ldots, n
\]

where \( C^c_i \) is the consumption of agricultural crops and \( C^m_i \) is the consumption of game meat in household \( i \). The utility function is assumed to have the regular properties, i.e. strictly quasi-concave with positive marginal utilities.

The agricultural crop production depends on effort use \( E^c_i \) and the amount of agricultural land \( L^i \), while we disregard the use of fertilizer, pesticides etc. In the same way as Barrett and Arcese (1998), one of Lopez’s models (1998), and Bulte and van Soest (1999), the land cultivated for crops is of fixed size. The production function is given as

\[
R^i = f(E^c_i; L^i),
\]

where output increases by a decreasing rate in effort, \( f_1 > 0 \) and \( f_{11} \leq 0 \). Wildlife roaming in the village area causes damage to agricultural production. Following Zivin et al. (2000) it is assumed that the damage increases with the size of the wildlife stock \( X \). The fraction of agricultural crops in household \( i \) destroyed by wildlife is \( DC^i = DC^i(X) \) where \( DC^i \in [0,1] \) and \( dDC^i/dX > 0 \) (see also Carlson and Wetzstein 1994). The net agricultural output is therefore given by

\[
R^i[1 - DC^i(X)].
\]

Game meat is produced through illegal hunting of wildlife. The wildlife harvesting function of household \( i \) is given by the Schaefer function as

\[
h^i = qE^h_i X,
\]
where $E^i_h$ is effort directed to hunting and $q$ is the catchability coefficient identical for all household. Let $M^i$ be the fixed endowment of effort in household $i$. The constraint on labour use reads

$$M^i = E^i_c + E^i_h$$

An alternative cost of effort use in hunting is therefore present.

It is assumed that the household consumption of agricultural crops is constrained by the net production as given in (4). The household sells excess crops on the market whenever the domestic consumption is below the level of crop production. In this case, the constraint in (4) is non-binding. Otherwise, the household produces crops for own consumption only, which means that the constraint is binding.

$$C^i_c \leq f(E^i_c; L^i) \left[ 1 - DC^i(X) \right]$$

The household maximizes its utility given the time constraint (3), the constraint on crop consumption in (4), and a budget constraint. The budget constraint is outlined as follows. The consumption of game meat in household $i$ consists of illegally harvested game meat $h^i$, and the legal game meat $S^i$ distributed from the management authorities. Following Barrett and Arcese (1998), $S^i$ is fixed and distributed freely to the household. Illegal and legal meat are considered homogenous in consumption and sold at the same price $P_m$ on the market. $Z^i$ is a fixed composed factor of labour-free income (e.g. money transfers from tourism), taxes and costs related to the purchase of basis goods (clothes, housing etc.). It is assumed that $Z^i > 0$ if the household receive ‘high’ transfers from tourism, while $Z^i < 0$ reflects ‘high’ fixed costs and taxes. Let $P_c$ be the unit price of agricultural crops. Then, the household faces the following budget constraint.$^4$

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$^4$ Hunting performed by the local people is illegal. However, the probability of being caught in illegal hunting and the resulting costs, such as imposed fine, imprisonment etc., are ignored in this analysis. When analysing the cross-sectional data set, these components are fixed and equal for every household and, therefore, omitted.
\[ P_i C^i_c + P_m C^i_m \]
\[ = P_i f(E^i_c, L^i) [1 - DC^i(X)] + P_m [qE^i_h X + S^i] + Z^i \]

If \( Z^i < 0 \) and the constraint on crop consumption is binding, the household is a net producer of meat, i.e. \( C^i_m < qE^i_h X + S^i \). This is also the case when the constraint on crop consumption is non-binding combined with a ‘high’ fixed cost \( Z^i \) \( (< 0) \). In this case, the household must sell excess meat on the market in order to finance the fixed cost. On the other hand, ‘high’ money transfers from tourism, i.e. \( Z^i \) is positive, and a non-binding constraint on crop consumption must be offset by net consumption of game meat, i.e. \( C^i_m > qE^i_h X + S^i \). In this case, the income from crops and the money transfers enable the household to purchase game meat from other poachers.

The decision problem of the household is to decide the optimal hunting effort \( E^i_h \) and consumption of agricultural crops \( C^i_c \) in order to maximize its utility, subject to the constraints in (3), (4) and (5). The first order conditions for maximum are given in Appendix 1. The resulting equation for the optimal hunting effort can be expressed as

\[ E^i_h = E(P_c, P_m, q, X, L^i, DC^i(X), S^i, M^i, Z^i) \geq 0 \]

An interior solution for \( E^i_h (>0) \) emerges when effort is directed to hunting until the marginal benefit of hunting equals the marginal cost (see Appendix 1). A corner solution takes place, i.e. \( E^i_h = 0 \), if the marginal cost of hunting exceeds the marginal benefit. The latter will be the case if the wildlife-induced damage to crops is ‘low’ and the price of agricultural crops relative to the price of game meat is ‘high’.

The household may produce agricultural crops for own consumption and trade any surplus on the market. However, the market fails for a particular household when it faces a ‘low’ price at

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5 The wildlife stock \( X \) is treated as exogenous in this model. In the same way as Lopez (1998), it is assumed that the household does not account for the stock effect when deciding upon the optimal hunting effort. Moreover, the ecological dynamics are not of focus in the present analysis. Instead, we investigate the labour use in illegal hunting and interpret more labour use as an increased pressure on the wildlife stock. See also the empirical specification of (6) in section 4.1.
which it can sell a crop. If this is the case, the household is better off by producing crops for own consumption only. That is, the constraint on crop consumption in (4) is binding. On the other hand, the individual household will sell excess crops on the market if the crop price is ‘high’. Then the production of crops exceeds the household consumption and, consequently, the constraint on crop consumption is non-binding. Recall from above that a ‘high’ relative price $P_c / P_m$, all else equal, drives the hunting effort towards zero. A higher crop price may therefore encourage the household both to sell crops on the market and to reduce the effort use in illegal hunting.

Given the optimal hunting effort and household consumption of crops, the consumption of game meat follows from the budget constraint in equation (5). The optimal effort in crop production results from the time constraint in equation (3). The comparative static is derived in Appendix 1. The sign of the respective derivatives depends on whether the constraint on crop consumption is binding. Assume first that the constraint is non-binding, i.e. the household sells excess crops on the market. In this case, the household behaves as if the production and consumption decisions are made sequentially. That is, in the first step the household solves the production problem by maximizing the income from crop production and illegal hunting. This gives the budget constraint. In the second step the household determines the optimal consumption bundle subject to the budget constraint (see Sadoulet and de Janvry 1995).

The comparative static results are straightforward with a non-binding constraint on crop consumption. First, the hunting decision is independent of the amount of game meat distributed from the culling programme. This result stems from the fact that increased endowment of meat represents a lump-sum transfer when there are competitive markets for both agricultural crops and game meat. Second, the household reacts to an increased market price for crops by directing less effort towards hunting. In the same way, more agricultural land increases the marginal productivity of labour in crop production which leads the household to increase the effort use in this activity at the expense of hunting. In contrast, the household responds to increased wildlife-induced damage to crops by directing more effort towards hunting. This is also the effect of a higher price for meat. Finally, the time spent hunting increases as the endowment of time, i.e. number of household members able to work, increases.
The effects are somehow different when the constraint on crop consumption is binding, i.e. when the household utilizes harvested crops for own consumption only. Contrary to the non-binding scenario, the household directs less effort towards hunting when a larger amount of game meat is distributed from the culling programme. The mechanism works as follows. First, the household substitutes its consumption of illegal game meat with legal game meat. Second, the income effect works in the direction of an increase in domestic crop consumption. Both effects lead the household to devote less effort on hunting.

In contrast to the non-binding scenario, the hunting decision is now made independently of the market price for agricultural crops. Obviously, this result holds only for an upper limit where the household choose not to sell crops on the market. The effect of increased endowment of agricultural land on hunting effort is ambiguous. First, more cultivated land increases the output of crops for a given \( E^i \). The household moderates the following effect on crop consumption by reducing its effort use in crop production. This is the direct effect and works in the direction of increased hunting effort. On the other hand, more land increases the marginal productivity of labour in crop production, which leads the household to devote less effort towards hunting. The total effect is therefore unclear. In the same way, increased damage in crop production has an ambiguous effect on hunting effort. The effect of a changing meat price is also ambiguous and strictly dependent on whether the household receive income transfers from tourism, i.e. whether it is a net consumer of meat. For net consumers \( Z^i > 0 \) a higher meat price reduces the real budget available to buy meat. Consequently, the household increases the hunting effort to substitute purchased meat with own illegal offtake. In contrast, a higher price of game meat increases the income for net producers of meat \( Z^i < 0 \). In this case, the household diverts less effort towards hunting. Finally, the effect of increased endowment of labour is positive and similar to the case of a non-binding constraint on crop consumption.

3. Data collection and descriptive analyses

3.1. Data collection

The empirical analysis of wildlife hunting is based on survey data from the Serengeti and Bunda Districts in Tanzania. Data was collected among 297 households in 6 villages of which half of the sample households live in villages which participate in the Serengeti Regional Conservation Project (SRCP). 166 households are from Bunda, while 131 households are
from Serengeti. For a further description of the survey, see Appendix 2. The questionnaire
deals with economic conditions and activities centred around the human-wildlife interface,
such as wildlife hunting, household income, and wildlife-induced damage to crops and
domestic animals, all for the year 2000. The households were also asked whether they
participate in agricultural crop production for own consumption or as an income generating
activity. The data on crop production cover mainly seven different crops: cotton, maize,
sorghum, cassava, millet, potatoes and beans. Cotton is the only cash crop, while the food
crops are produced both for sale on the market and as food for the household, or for
household consumption only. Among the food crops, maize is the main income-generating
crop. In addition to crop production and domestic animal keeping, 37 per cent of households
in the study area earn income from selling fish, charcoal, local brew, running small shops etc.
In the following, these activities will be referred to as ‘other’ activities. Finally, to add to
income and domestic consumption, people go hunting.

One main purpose of the empirical analysis is to investigate SRCP’s impact on the illegal
hunting activity in this area. This project currently includes fourteen villages spread evenly
between Serengeti and Bunda Districts. The selection of the project villages has not been
based on thorough studies of illegal activities, but is based on their closeness to the western
borders of Serengeti National Park. As mentioned, SRCP’s main strategy is to manage the
game-culling programme. The culling quota is set as equal for each project village and
determined by the government, i.e. the Ministry of natural resources and tourism. The
responsibility of SRCP is to organize the hunting and distribute the offtake to the respective
villages. The villagers buy the meat at a price set in agreement between SRCP and the village
authorities.

In addition to game meat distribution, SRCP has assisted the establishment of village-level
institutions responsible for managing the fund from the hunting quota revenues. These funds
finance village projects such as schools and dispensaries which, in turn, has reduced the
individual tax burden. SRCP is also responsible for the set-up and training of game scouts in
the project villages. Finally, SRCP works with awareness building in order to improve the

\[\text{footnote text}\]

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\[\text{footnote text}\]
relationship between the local people and the park. This includes public meetings at village level, seminars and training courses on wildlife utilization and management etc. For a broader overview of the activities of SRCP, see Rugumayo (1999)⁹. In the present analysis, four of the sample villages participate in SRCP¹⁰, while there exists no village project in the sample villages outside SRCP¹¹.

3.2. **Descriptive analysis and the sample**

The households were asked about their participation in illegal hunting, hunting trips and travel distance to the hunting area. The data on hunted species covers wildebeest, zebra, gazelle, topi, and impala. Table 1 shows that 80 households, or 27 per cent of the sample, report that some household members are involved in illegal hunting. The participation rate in illegal hunting differs between sub-groups of the sample. For instance, the participation rate is 32 per cent among SRCP households and 22 per cent for households outside SRCP. These differences demonstrate the need for a further investigation of the impact of SRCP on illegal hunting. In addition, the participation rate varies between the districts, 22 per cent in Bunda District and 34 per cent in Serengeti District.

<table>
<thead>
<tr>
<th>Hunting</th>
<th>Number</th>
<th>Participation</th>
<th>No participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sample</td>
<td>297</td>
<td>80 (27%)</td>
<td>217 (73%)</td>
</tr>
<tr>
<td>SRCP</td>
<td>148</td>
<td>47 (32%)</td>
<td>101 (68%)</td>
</tr>
<tr>
<td>Not SRCP</td>
<td>149</td>
<td>33 (22%)</td>
<td>116 (78%)</td>
</tr>
<tr>
<td>Bunda District</td>
<td>166</td>
<td>36 (22%)</td>
<td>130 (78%)</td>
</tr>
<tr>
<td>Serengeti District</td>
<td>131</td>
<td>44 (34%)</td>
<td>87 (66%)</td>
</tr>
</tbody>
</table>

Table 2 demonstrates that we can divide the hunters into two groups. This division is also important for the empirical specification of the model (see section 4.1). We have one group of hunters who report that they go on hunting trips and a second group of hunters who don’t go

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⁹ SRCP intends to assist with loans and other kind of support to promote income-generating projects among the project villages. However, this is a small-scale project which is reflected by the fact that only 9% of the sample households participating in SRCP report that they benefit from this kind of assistance.

¹⁰ The project was implemented in Robanda and Nyakiton (Serengeti) in 1993, and in Nyamatoke and Mariwanda (Bunda) in 1994.

¹¹ The village executive secretary in both Bukore and Rwamchanga village confirmed the absence of village projects.
on hunting trips. 55 per cent of the hunters go on hunting trips, i.e. trips that last for several
days and where the hunters usually hunt within the protected area. Wildebeest is the major
target for this group, followed by zebra and gazelle. The remaining 45% of the hunters hunt
closer to their homes and within the village area. For this group, hunting is carried out during
the annual wildebeest migration when wildebeest enters village land during the dry season.12
Several of these households report that they kill wildebeest when they enter their agricultural
field or yard. This indicates that hunting in the home area is less time consuming than going
on hunting trips.

<table>
<thead>
<tr>
<th>Table 2: Distribution of the households involved in hunting.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>SRCP</td>
</tr>
<tr>
<td>Not SRCP</td>
</tr>
<tr>
<td>Bunda District</td>
</tr>
<tr>
<td>Serengeti District</td>
</tr>
</tbody>
</table>

As seen in Table 2, the fraction of the hunters reporting a positive number of hunting trips
differs between sub-groups of the sample. For instance, 43 per cent of the hunters in the
SRCP villages report that they go on hunting trips, while the same rate for hunters outside
SRCP is 73 per cent. The rates differ even more between the districts: 86 per cent of the
hunters in Bunda go on hunting trips, while only 30 per cent of the hunters in Serengeti report
the same. When it comes to the motivation for hunting, both groups of hunters report that they
hunt both as a source of income and for domestic consumption. However, the groups differ
when it comes to the reported income from illegal hunting. While 96 per cent of the
households going on hunting trips earn income from this activity, this only applies to 33 per
cent of those who hunt in their home area.13 One plausible explanation of the observed

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13 It is important to note that distinguishing between hunting in the protected area and the village area as done here
must not be confused with the terms ‘subsistence’ and ‘organized’ poaching used by Leader-Williams and Milner-
Gulland (1993). The ‘organized’ poacher gangs of Leader-Williams and Milner-Gulland originate from outside
the local community of the study area Luangwa Valley, Zambia. In addition, they use more sophisticated hunting methods
(i.e. automatic weapons) and hunt more often for trophies (i.e. elephant and rhino), than the subsistence hunters. Here,
however, all hunters originate from the local community, they all hunt for meat (for domestic consumption or to sell),
and they all use traditional hunting methods (i.e. wire snares, pitfall traps, knives, machetes etc. (see Arcese et al.
1995)). Therefore, in line with Leader-Williams and Milner-Gulland’s terminology, both groups of hunters in this
survey are subsistence hunters.
deviation in income is that the average offtake is considerably higher among households who go on hunting trips (see Table A1 in Appendix 3).

Between the districts, the data set reveals different participation rates in three income-generating activities, where some households earn income from several of these activities. While Table 3 clearly shows that crop production is the most common income generating activity among the sample households, the rate of households with income from this activity differs between the districts. All of the households in Bunda District possess agricultural land and 86 per cent earn income from crop production. 81 per cent of the Bunda households earning income from crops grow cotton, while 52 per cent grow maize. Table 3 also shows that crop production is a major activity in Serengeti where 60 per cent of the households earn income from crops. In comparison with Bunda, only 11 per cent of the Serengeti households who earn income from crops devote land for cotton, while 94 per cent of these households grow maize. It turns out that the mean income from crops is significantly higher in Bunda than in Serengeti (see Appendix 3, Table A2), a result which may partly be due to the discovered difference in crop composition: while cotton is the only cash crop in the study area, maize is produced for both domestic consumption and as a source of income.

Table 3: Number of households earning income from the various activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Crop</th>
<th>Domestic animals</th>
<th>‘Other’*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sample</td>
<td>220</td>
<td>153</td>
<td>110</td>
</tr>
<tr>
<td>Bunda District**</td>
<td>142</td>
<td>74 (45%)</td>
<td>67 (40%)</td>
</tr>
<tr>
<td>SerengetiDistrict**</td>
<td>78 (60%)</td>
<td>79 (60%)</td>
<td>43 (33%)</td>
</tr>
<tr>
<td>SRCP**</td>
<td>100</td>
<td>58 (39%)</td>
<td>66 (45%)</td>
</tr>
<tr>
<td>Not SRCP**</td>
<td>120</td>
<td>95 (64%)</td>
<td>44 (30%)</td>
</tr>
</tbody>
</table>

*‘Other’ income does not include hunting.
**Per cent of the number of sample households in the respective sub-group.

Table 3 shows that animal keeping is the second major activity in the study area. The households mainly hold cattle, goat, sheep, and poultry. The rate of households with a positive income from animal keeping is higher in Serengeti than in Bunda. Moreover, the mean income from animal keeping is significantly higher among the Serengeti households (see Appendix 3, Table A2). Finally, as seen in Table 3, 110 households earn income from other activities than crop production and domestic animal keeping. Again, the rate of
participation differs between the districts, 40 per cent in Bunda and 33 per cent in Serengeti. The mean income from ‘other’ activities is significantly higher in Serengeti (see Appendix 3, Table A2). However, we find no significant difference in the mean total income (except hunting) between the districts. Hence, while the districts differ in type of income generating activities, there is no significant difference in the mean income level.

When grouping the households by participation in SRCP, Table 3 shows that the rate of households with income from crops, domestic animals and other activities differ between the sub-groups. The rate of households earning income from crops and/or domestic animals is lower among SRCP households than those outside SRCP. Moreover, the mean income from each of these activities is significantly lower among the SRCP households (see Appendix 3, Table A2). In contrast, a higher rate of the SRCP households earns income from ‘other’ activities. However, the mean income from these activities does not differ significantly between the sub-samples. Still, the mean total income is significantly higher outside SRCP (see Appendix 3, Table A2).

The households were asked to indicate the level of wildlife-induced damage to crops and domestic animals as ‘no damage’, ‘very little’, ‘much’ or ‘very much’. Table 4 reports the answers. The second row shows that some 86 per cent of the respondents complain that wildlife causes ‘much’ or ‘very much’ damage to crops. This number seems high, and a further investigation of the percentage damage reported by the individual household shows a considerable variation within each response category. However, the survey reveals that the mean percentage damage increases between the categories and the means differ significantly. Still, there are some serious measurement problems regarding both of the reported measures of crop damage. First of all, the respondents may over-estimate the damage in the hope for future compensations. Second, the individual respondent estimated the percentage damage to his crops as the number of cultivated acres damaged relative to the number of acres cultivated. This may cause both over and under estimation of the money value of the damage as one acre of cotton (cash crop) is given the same weight as e.g. sorghum (food crop).

Table 4 also shows the distribution of the reported damage to domestic animals. As seen in the fifth row, some 60 per cent complain that wildlife causes ‘much’ or ‘very much’ damage. Compared to the reported crop damage, far more households respond that they experience ‘no damage’ to domestic animals. When it comes to the number of animals killed or injured by
wildlife, we distinguish between damage to poultry on one hand and damage to bigger animals like cattle, goats and sheep on the other. The term livestock in Table 4 refers to bigger animals. The reported numbers vary considerably within each respond category. Some inconsistency may be present, but the variation may also reflect varying dependence on domestic animal keeping among the households.

Table 4: Distribution of reported wildlife-induced damage to crops and domestic animals.

<table>
<thead>
<tr>
<th>Response categories:</th>
<th>No damage</th>
<th>Very little</th>
<th>Much</th>
<th>Very much</th>
<th>Total</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop damage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of respondents</td>
<td>24</td>
<td>18</td>
<td>72</td>
<td>180</td>
<td>294</td>
<td></td>
</tr>
<tr>
<td>% of respondents</td>
<td>8.2</td>
<td>6.1</td>
<td>24.5</td>
<td>61.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Mean % damage</td>
<td>1.7</td>
<td>12.3</td>
<td>17.8</td>
<td>22.6</td>
<td>19.1</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Damage domestic animals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of respondents</td>
<td>73</td>
<td>12</td>
<td>70</td>
<td>55</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>% of respondents</td>
<td>34.8</td>
<td>5.7</td>
<td>33.3</td>
<td>26.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Mean poultry lost/injured</td>
<td>1.2</td>
<td>2.7</td>
<td>5.5</td>
<td>9.4</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Mean livestock lost/injured**</td>
<td>0.25</td>
<td>2.3</td>
<td>2.0</td>
<td>3.4</td>
<td>1.9</td>
<td></td>
</tr>
</tbody>
</table>

*P is the observed significance level. The null hypothesis of equal means is rejected for $P \leq 0.05$

**Here, ‘livestock’ includes cattle, goats and sheep.

4. Empirical specification and estimation results

4.1. Empirical specification

The sample used in the following empirical analysis is limited to the 80 households who report that they are involved in illegal hunting. In equation (6) the hunting effort $E_h$ was defined as time spent on illegal hunting. The data set provides information on the number of hunting trips in 2000. In addition, for households reporting that they go on hunting trips, the data set states the average number of days per trip. However, for households hunting in their home area only (i.e. involved in illegal hunting but no trips, see Table 2), we lack information about how much time they spend hunting. For all these reasons, hunting effort is defined as the number of hunting trips, where $E_h > 0$ for those who go on hunting trips, while $E_h = 0$ for those who hunt in their home area. This means that the empirical analysis is related to the number of hunting trips rather than the actual time spent hunting. Still, this specification of the dependent variable is reasonable because the offtake is significantly higher among hunters who go on hunting trips (see Appendix 3, Table A1). Hence, there seems to be a potential for
reduced aggregate illegal offtake when stimulating reduced hunting effort, i.e. reduced
number of hunting trips per year.

Because we have data on the actual number of hunting trips for the households with a positive
number of trips, we specify the empirical model as a Tobit model. The basic equation to be
estimated is given in (7) where the number of hunting trips in household $i$ $E_h^i$ is positive for
the 44 sample households who go on hunting trips, while $E_h^i = 0$ for the 36 sample
households who hunt within their home area$^{14}$.

$$E_h^i = \begin{cases} E_h^i & \text{if } E_h^i > 0 \\ 0 & \text{if } E_h^i = 0 \end{cases}, \text{ where}$$

$$E_h^i = \beta_0 + \beta_1 SRCP + \beta_2 DISTRICT + \beta_3 L^i + \beta_4 Y^i + \beta_5 DC^i + \beta_6 DY^i + \beta_7 M^i + u^i$$

Note that the wildlife stock $X$ is omitted from the empirical model. This is done because there
exists no data on the distribution of the wildlife stock in relation to the location of the sample
villages. Consequently, we must consider the wildlife stock as equally distributed within the
study area and, hence, the stock size is equal for every village and household and, therefore,
 omitted from the model$^{15}$.

The explanatory variable $SRCP$ in (7) is specified as a dummy for participation in the SRCP
project. $DISTRICT$ is a dummy for the district and is included in order to capture district-
specific characteristics of the data set. The districts differ in several ways. First, and as
already discussed, the crop composition in agricultural production varies in that cotton is
produced mainly in Bunda. Second, the size of the human population in the sample villages in
Bunda exceeds the one of the Serengeti villages, which may imply a bigger local market in
Bunda. In addition, the villages in Bunda are located closer to a city, i.e. Bunda Town, and the
market place there. The sample villages in Serengeti are located closer to the park
management authority’s headquarters, which may influence the interaction between the

$^{15}$ See Campbell and Borner (1995) for estimates of the wildlife population in the Serengeti ecosystem.
management authority and the local people. Because of these differences, it is adequate to control for the district in the empirical analysis.

The explanatory variable $L^i$ is the number of acres cultivated for crop production in household $i$. $DC^i$ is a discrete variable on crop damage reflecting the four response categories ranging from ‘no damage’ to ‘very much damage’. As seen in Table 3, domestic animal keeping is a common activity among the sample households. Therefore, we introduce the size of the herd $Y^i$, measured by the number of domestic animals, and wildlife-induced damage to this herd $DY^i$ as explanatory variables. $DY^i$ is a discrete variable in the same way as for the crop damage. We expect that an increased size of the domestic stock and/or reduced damage to this stock will increase the marginal return from animal keeping and stimulate the household to direct less effort towards illegal hunting. $M^i$ is the number of household members and we expect that the hunting effort increases with the size of the household. However, it is important to note that this explanatory variable counts all members of the households, frequently ranging from small children to elders. Consequently, this is not an adequate measure of number of household members capable of working. Still, it is worthwhile to investigate the impact of this kind of household characteristic. Finally, $u^i$ is the error term. Summary statistics of the variables are reported in Table A2 in Appendix 3.

Equation (7) is the basic empirical model. However, later this model will be modified in order to capture patterns in crop production and domestic animal keeping, income from other legal activities than agricultural production, and game meat bought from SRCP. When investigating the impact of domestic animal keeping we will distinguish between the poultry and bigger animals like cattle, goat, and sheep. $POULTRY^i$ counts the number of poultry in household $i$, while the variable $LIVESTOCK^i$ measures the number of domestic animals except poultry. The explanatory variable $OTHER^i$ captures the income from other activities than agricultural production and illegal hunting in household $i$. We will also introduce the variable $MEAT^i$ which indicates the number of kilo game meat bought from SRCP in household $i$ year 2000. This is a discrete variable ranging from ‘<5kg’, ‘[5, 10]kg’, ‘[11, 20]kg’, ‘[21, 30]kg’, to ‘>30kg’.

Explanatory variables for the number of acres directed to the production of cotton $L^i_{COT}$ and maize $L^i_{MAI}$ will also be included. In addition, because some crops are produced for
both own consumption and the market, it is necessary to compute an index working as a proxy for the degree of crop production for own consumption in the respective household. The households were asked to indicate whether a particular crop is produced for own consumption and/or for sale on the market. They also specified how many acres of land they devote for each crop. The index is based on this information and defined as follows. First, let \( L_{kj}^i \) be the number of acres devoted to crop \( j \in [1,v] \) by household \( i \in [1,n_k] \) in district \( k \in [0,1] \). Then, the total number of acres cultivated for crop production in household \( i \) in district \( k \) is \( \sum_{j=1}^v L_{kj}^i \). Second, let \( \omega^i_k \) be the share of the households in district \( k \) who produce crop \( j \) for own consumption only. The index of crop production for own consumption in household \( i \) district \( k \) is then given by

\[
INDEX_k^i = \frac{\sum_{j=1}^v \omega^i_k L_{kj}^i}{(\sum_{j=1}^v L_{kj}^i)}
\]

The index is district specific in the sense that it is based on consumption shares in the respective district. An increase in \( INDEX_k^i \) means that a higher share of crop production in household \( i \) in district \( k \) is used for own consumption only.

4.2. Estimation results

Table 5 reports the Tobit estimates for the basic model in (7) as well as the additional regressions. The coefficient of the political variable \( SRCP \) in the basic regression (a) has a significant negative sign, which suggests that SRCP has succeeded in reducing the number of hunting trips in the study area. This is also the case for regressions (c) to (d). However, we cannot state from which activities of SRCP this result stems from. For instance, the dummy variable \( SRCP \) may reflect the culling programme where game meat is distributed to the project villages. In order to investigate the impact of game meat distribution, the SRCP households who report that they buy game meat from this programme (i.e. 94 per cent) were asked to estimate the number of kilo meat bought (see section 4.1). This gives the discrete variable \( MEAT \) in regression (e). The coefficient is not significantly different from zero, which means that we cannot reject the null hypothesis saying that game meat distribution has no effect on hunting effort. Instead, the significant negative sign of \( SRCP \) in regression (a)-(d) may reflect the presence of village game scouts and the establishment of village wildlife funds.
which may have reduced the antagonism towards wildlife in the SRCP villages. It is also possible that SRCP’s attempts on awareness building have affected the villagers’ attitude towards wildlife in the same direction.

The coefficient of \( L \) in the basic regression (a), the amount of land cultivated for crop production by the household, is negative but not significantly different from zero. As discussed in section 3.1 the crop composition differs between the districts in that cotton – the main crop in Bunda – is produced for the market, while maize – the main crop in Serengeti – is produced both for the market and household consumption. Regression (b) controls for the different patterns of crop production by distinguishing between land devoted to cotton and land devoted to maize. The coefficient of \( L_{COT} \) comes out as negative and significantly different from zero. The coefficient of \( L_{MAI} \) is also negative, but only significant on the 10 per cent significance level. Both results are in accordance with the theoretical model of a net producer of agricultural crops. The sign of the coefficient of \( L \) in regression (b) is positive but not significant. However, the sign differs from regression (a), which may indicate that the hunting effort increases if additional land is used for a subsistence food crop. Therefore, regression (c) makes a distinction between crop production for own consumption and crop production for the market by introducing \( INDEX \) as an independent variable. The coefficient is positive and significantly different from zero, which means that peasants with a higher degree of subsistence crop production devote more effort towards hunting. In order to reduce the hunting effort, the policy implication is therefore to provide for easier access to the market for agricultural crops.

The underlying theoretical model predicts that wildlife-induced damage to crops leads to an increase in the hunting effort when the peasant is a net producer of crops, whereas the effect is ambiguous when crops are produced for own consumption only. The estimated coefficients in regressions (a) to (d) square with the hypothesis that damage to crops increases the hunting effort. The sample in regression (f) counts the households reporting that they earn no income from crop production, i.e. crop production for own consumption only. Also here the coefficient comes out as positive and significantly different from zero.

Regressions (a) to (c) report that the impact on the hunting effort of more extensive wildlife-induced damage to domestic animals is positive and significantly different from zero. This result, together with the findings for crop damage above, supports the widespread view that
damage induces a shift in labour use towards wildlife extraction (see Skonhoft and Solstad (1998) for a theoretical analysis and Kiss (1990) for a broader discussion of the costs of living with wildlife). This suggests that policies which support a tighter damage control, such as fencing, chasing problem animals out of the villages and so forth, will reduce the hunting pressure and increase the degree of wildlife conservation.

Table 5: Estimation results. Tobit model. Dependent variable $E_h$.

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SRCP</strong></td>
<td>-4.195</td>
<td>-4.147</td>
<td>-4.197</td>
<td>-4.211</td>
<td></td>
<td>-4.513</td>
</tr>
<tr>
<td></td>
<td>(-4.63)</td>
<td>(-5.13)</td>
<td>(-5.07)</td>
<td>(-5.09)</td>
<td></td>
<td>(-2.20)</td>
</tr>
<tr>
<td><strong>MEAT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.888</td>
<td>6.560</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.70)</td>
<td>(2.72)</td>
</tr>
<tr>
<td><strong>DISTRICT</strong></td>
<td>3.914</td>
<td>4.185</td>
<td>3.922</td>
<td>3.945</td>
<td>4.413</td>
<td>6.007</td>
</tr>
<tr>
<td></td>
<td>(4.63)</td>
<td>(4.80)</td>
<td>(5.29)</td>
<td>(5.33)</td>
<td>(3.47)</td>
<td>(2.26)</td>
</tr>
<tr>
<td><strong>L</strong></td>
<td>-0.125</td>
<td>0.259</td>
<td></td>
<td></td>
<td>0.181</td>
<td>0.313</td>
</tr>
<tr>
<td></td>
<td>(-0.76)</td>
<td>(1.37)</td>
<td></td>
<td></td>
<td>(1.06)</td>
<td>(0.82)</td>
</tr>
<tr>
<td><strong>L_COT</strong></td>
<td>-0.791</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.19)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L_MAI</strong></td>
<td>-0.551</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.76)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INDEX</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.379</td>
<td>6.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.49)</td>
<td>(2.26)</td>
</tr>
<tr>
<td><strong>Y</strong></td>
<td>-0.156</td>
<td>-0.165</td>
<td>-0.159</td>
<td>-0.219</td>
<td>-0.193</td>
<td>-0.232</td>
</tr>
<tr>
<td></td>
<td>(-3.53)</td>
<td>(-3.98)</td>
<td>(-4.21)</td>
<td>(-2.14)</td>
<td>(-2.03)</td>
<td></td>
</tr>
<tr>
<td><strong>POULTRY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.172</td>
<td>(-3.77)</td>
</tr>
<tr>
<td><strong>LIVESTOCK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.144</td>
<td>(-3.04)</td>
</tr>
<tr>
<td><strong>DC</strong></td>
<td>1.918</td>
<td>2.170</td>
<td>1.825</td>
<td>1.820</td>
<td>5.980</td>
<td>6.666</td>
</tr>
<tr>
<td></td>
<td>(2.77)</td>
<td>(3.34)</td>
<td>(2.94)</td>
<td>(2.97)</td>
<td>(3.02)</td>
<td>(2.45)</td>
</tr>
<tr>
<td><strong>DY</strong></td>
<td>1.790</td>
<td>1.665</td>
<td>1.904</td>
<td>1.905</td>
<td>2.598</td>
<td>3.250</td>
</tr>
<tr>
<td></td>
<td>(4.73)</td>
<td>(4.42)</td>
<td>(5.42)</td>
<td>(5.44)</td>
<td>(3.62)</td>
<td>(3.26)</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td>-0.029</td>
<td>-0.021</td>
<td>-0.023</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.07)</td>
<td>(-0.80)</td>
<td>(-0.85)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>-0.297</td>
<td>-0.316</td>
<td>-0.313</td>
<td>-0.317</td>
<td>-1.108</td>
<td>-0.400</td>
</tr>
<tr>
<td></td>
<td>(-2.01)</td>
<td>(-2.37)</td>
<td>(-2.64)</td>
<td>(-2.68)</td>
<td>(-2.83)</td>
<td>(-0.71)</td>
</tr>
<tr>
<td><strong># obs.</strong></td>
<td>58</td>
<td>57</td>
<td>55</td>
<td>55</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td><strong>R^2_adj</strong></td>
<td>0.270</td>
<td>0.314</td>
<td>0.328</td>
<td>0.329</td>
<td>0.286</td>
<td>0.386</td>
</tr>
</tbody>
</table>

Note: a coefficient is significantly different from zero at level of 5 per cent for $|t| > 2$.
In regressions (a) to (c) the number of domestic animals comes out with a negative sign and the coefficient is significantly different from zero. There are two possible reasons for this result: first, more domestic animals may increase the time spent herding and, second, it may reduce the consumption of game meat via a substitution effect, both of which lead the household to devote less effort towards hunting. Regression (d) distinguishes between livestock (i.e. cattle, goat, and sheep) and poultry keeping and demonstrates negative significant effects of both. Livestock herding is a relatively time-consuming activity and, consequently, the negative coefficient may reflect that the household responds to more livestock by increasing the labour use in this activity. In contrast, because poultry keeping is less time-consuming, the negative coefficient may reflect that poultry is a substitute for game meat in consumption.

The theoretical model assumes that the household is involved in two activities only; crop production and illegal hunting. Above, we also looked at the estimated effects of domestic animal keeping. However, 46 per cent of the sample households report that they earn income from other activities as well. In regression (b) to (d) the coefficient of the income from these activities OTHER is positive, but not significantly different from zero, which supports the theoretical model.

5. Discussion and concluding remarks

The incentives to hunt illegally are detrimental for wildlife conservation in protected areas in developing countries. Despite of this, little empirical attention has been paid to the underlying motivation for illegal hunting. Knowledge about this issue is crucial for providing sound advice to policymakers in order to reach the joint aim of wildlife conservation and economic development.

This paper estimates functions for labour effort in illegal hunting, where the number of hunting trips serves as a proxy for labour use. The analysis provides several policy recommendations that have the potential of reducing the number of hunting trips and thereby promoting wildlife conservation. Cross-sectional data from a household survey in western Serengeti is used to identify factors determining the labour use in illegal hunting in this area. First, the empirical results suggest that the establishment of the ICDP in western Serengeti, i.e. the Serengeti Regional Conservation Project (SRCP), has reduced the illegal hunting pressure. However, it is important to note that we cannot draw a conclusion on the
conservation effect of SRCP based on this result alone. SRCP exercises game culling and we do not know how this has affected the aggregate wildlife offtake. Further investigations of the extent of the culling programme relative to the illegal offtake is therefore of major importance.

Second, the empirical analysis reveals another important relationship, namely that hunting in western Serengeti is related to the patterns in agricultural crop production. The estimation results demonstrate that a higher degree of cotton production and other crop production for the market stimulate to increased effort in agricultural production and a reduced illegal hunting pressure. In Bunda District, policies which stimulate increased cotton production, e.g. more extensive use of pesticides and irrigation systems, have the potential of reducing the hunting pressure.

The number of cotton buyers visiting Bunda District during the harvest period reflects that the access to the market for cotton is relatively easy for the households in this district. However, the situation is somehow different in Serengeti District, where people complain about poor access to market. It is therefore important to stimulate increased accessibility to market for the households in this district. One important challenge is to improve the infrastructure in the area, for instance through road construction, in order to reduce the transaction costs. In addition, support of fertilizer use and pesticides will reduce the costs of crop production and, hence, encourage the peasants to participate in the market. However, policymakers should be aware of possible trade-offs between such improvements and environmental degradation. For instance, road construction may facilitate the illegal transport of wildlife products out of this area and make them more tradable. Infrastructure improvements should therefore be combined with more extensive use of anti-poaching law enforcement.

Wildlife imposes damage to crops and domestic animals and the empirical results indicate that this increases the illegal hunting. This result should encourage policymakers to make initiatives to reduce and prevent wildlife-induced damage, such as support of fencing, chasing problem animals out of the villages, and so forth. Another option is to compensate the local peasants for the costs of living with wildlife. There are, however, some obvious pitfalls related to this strategy; people may overestimate the damage and a compensation scheme may attract people from other areas and thereby increase the human pressure on the park borders.
We have also seen in this analysis that the hunting pressure is negatively related to domestic animal keeping. Policies which stimulate the local people to keep more animals will therefore reduce the hunting pressure in the study area. However, policymakers should be aware that more livestock (i.e. cattle, goat, and sheep) means more intensive grazing, which may reduce the quality of the wildlife habitat. The long-term consequence for wildlife conservation is therefore highly unclear. However, poultry does not compete with wildlife in the same way as grazing animals. A better strategy for promoting wildlife conservation is therefore to support poultry keeping.

In summary, the empirical results suggest that SRCP has succeeded in reducing the illegal hunting pressure in Serengeti. Other initiatives that may promote wildlife conservation include attempts which encourage a higher degree of crop production for the market and more extensive use of damage control. Moreover, the empirical results suggest the best strategy for achieving a joint objective of wildlife conservation and economic development. While the implementation of SRCP has reduced the illegal hunting pressure, we do not know the impact on the wildlife stock. In addition, records from SRCP show an average expected revenue from the culling programme of 834 000 tzh per village in 2000, or some 2 300 tzh per household. This is low compared to the potential return from agriculture where the average income from crops among the cotton producers was 88 000 tzh (see Appendix 3, Table A4). These numbers indicate that the individual income-advantage of participating in SRCP is highly limited. In order to promote both wildlife conservation and local welfare policymakers should instead make arrangements which encourage and ease the access to markets for agricultural crops.
References


Appendix 1: Optimisation and comparative static

Solving equation (5) for $C^i_m$, equation (3) for $E^i_c$ and inserting in (l) yields

$$U^i = U \left[ C^i_c, \left[ f(M^i - E^i_h; L') (1 - DC^i(X)) - C^i_c \right] \left( P^c / P^m \right) + qE^i_h X + S^i + Z^i / P^m \right]$$

The decision problem of the household is therefore to determine the optimal hunting effort $E^i_h$ and crop consumption $C^i_c$ in order to maximize its utility. The Lagrange function reads

$$V^i = U \left[ C^i_c, \left[ f(M^i - E^i_h; L') (1 - DC^i(X)) - C^i_c \right] \left( P^c / P^m \right) + qE^i_h X + S^i + Z^i / P^m \right] - \lambda \left[ C^i_c - f(M^i - E^i_h; L') (1 - DC^i(X)) \right].$$

The first order conditions are given by

\[ (A1) \quad U^c m \left[ qX - \left( P^c / P^m \right) f_1(M^i - E^i_h; L') \left[ 1 - DC^i(X) \right] \right] - \lambda f_1(M^i - E^i_h; L') \left[ 1 - DC^i(X) \right] \leq 0; = 0 \quad \text{if} \quad E^i_h > 0 \]

\[ (A2) \quad U^c - U^m \left( P^c / P^m \right) - \lambda \leq 0; = 0 \quad \text{if} \quad C^i_c > 0 \]

where $U^c$ and $U^m$ denote the first order derivative with respect to $C^i_c$ and $C^i_m$, respectively, while $f_1$ denotes the first order derivative with respect to $E^i_c$. $\lambda \geq 0$ is the shadow value of crop consumption and states that the utility in optimum either increases or is not affected by a positive shift in the net crop output, e.g. reduced crop damage. In the case of a non-binding constraint on crop consumption, the household sells excess crops on the market, which drives the shadow value to zero, $\lambda = 0$. When the market for crops fails, the consumption of crops is constrained by the net production in the sense that the household produces crops for own consumption only. This gives a positive shadow value, $\lambda > 0$. (A1) and (A2) determine $E^i_h$ and $C^i_c$, while the effort use in agriculture $E^i_c$ and the consumption of game meat $C^i_m$ follow from equations (3) and (5), respectively.

First, consider the case of a non-binding constraint on crop consumption. Then, in case of an interior solution, (A1) is reduced to

\[ (A1') \quad qX - \left( P^c / P^m \right) f_1(E^i_c; L') \left[ 1 - DC^i(X) \right] = 0 \]

which determines the optimal hunting effort $E^i_h$. Differentiation of $(A1')$ gives
Second, consider the case of a binding constraint on crop consumption, i.e. 
\[ C^i_c = f(E^i_c; L^i) (1 - DC^i (X)) \] and \( \lambda > 0 \). Then (5) gives \( C^i_m = qE^i_h X + S + Z^i / P_m \). Solving (A2) for \( \lambda \) and inserting this in (A1) gives the first order condition for an interior solution as

\[
(A3) \quad U_m qX - U_c f_i(E^i_c; L^i)(1 - DC^i (X)) = 0
\]

Differentiation of (A3), when accounting for the time constraint in (3), gives the comparative static results (\( \sigma < 0 \) from the second order maximum condition for \( E^i_h \)):

\[
\frac{dE^i_h}{dS^i} = \frac{-U_{mm} qX + U_{cm} f_i (1 - DC^i) }{\sigma} < 0
\]

\[
\frac{dE^i_h}{dP_m} = \left[ U_{mm} qX - U_{cm} f_i (1 - DC^i) \right] Z^i / P_m^2 / \sigma
\]
\[
\frac{dE_h^i}{dP_c} = 0
\]

\[
\frac{dE_h^i}{dL^i} = \frac{(1 - DC^i)\left[U_c f_{12} + U_{cc} f_1 f_2 (1 - DC^i) - U_{mc} q X f_2\right]}{\sigma}
\]

\[
\frac{dE_h^i}{dDC^i} = \frac{U_{mc} q X - U_c f_1 - U_{cc} f_1 (E^i_c + L^i_f) f_1 (1 - DC^i)}{\sigma}
\]

\[
\frac{dE_h^i}{dM^i} = \frac{(1 - DC^i)\left[U_c f_{11} + U_{cc} f^2_1 (1 - DC^i) - U_{mc} q X f_1\right]}{\sigma} > 0
\]
Appendix 2: The survey

During the period of June-August 2001 I conducted interviews in 297 households in Serengeti and Bunda Districts. In order to capture the human-wildlife interface, six villages located along the western border of the Serengeti National Park were selected for participation in the survey. The villages are Bukore, Mariwanda, and Nyamatoke in Bunda District and Nyakitono, Robanda, and Rwamchanga in Serengeti District. Four of these villages participate in SRCP, namely Nyamatoke, Mariwanda, Nyakitono, and Robanda. The households were picked at random from lists of names, and the number of households from each village was decided by weighting the villages by their respective size. In each household, whenever possible, the head of the household was interviewed. The interviews were conducted in Kiswahili with translation assistance from two local Tanzanians.

Based on experience from test interviews in Bukore, a strategy was developed on how to approach the questionnaire in general and especially the sensitive questions on illegal hunting. In order to gain confidence from the local people, we spent much time in the villages and had two inhabitants in each village to visit the households in advance and explain the purpose of the survey. The interviews took place in the home of the respective household.

The households were asked whether any of the household members were involved in hunting in 2000. Those who answered yes were asked additional questions in order to capture the extent of the hunting activity. None of the respondents have a licence to hunt, which means that all hunting recorded in this survey is illegal. People submitted information about the number of hunting trips, the number of days spent per hunting trip, and the average travel distance per trip. However, we discovered that some of the hunters hunt within their home area only, especially during the annual wildebeest migration. The questions on trips and distance were therefore omitted for this group.

Some caveats should be made as the data set have a few weaknesses that are common for questionnaires. First, information on income is likely to be understated because some respondents are suspicious and fear that the information will be handed over to the district and central government for taxation purposes. Second, the quantitative data on plot size under various agricultural uses are given by the respondent’s subjective estimate, which may be subject to errors. The same applies to the estimated wildlife-induced damage to crops and livestock. The reader should be aware of these problems when reading the paper.
### Appendix 3: Tables

#### Table A1: Mean wildlife offtake per household in 2000 for households involved in hunting. Kruskal-Wallis test.

<table>
<thead>
<tr>
<th>Hunting trips?</th>
<th>Yes</th>
<th>No</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (st. dev.)</td>
<td>13.86 (30.39)</td>
<td>2.25 (1.99)</td>
<td>0.000</td>
</tr>
<tr>
<td>N**</td>
<td>N=43</td>
<td>N=36</td>
<td></td>
</tr>
</tbody>
</table>

*P is the observed significance level. The null hypothesis of equal means is rejected for $P \leq 0.05$.

**The third row reports the number of observations in the respective sub-sample. Here, one observation is missing among those who go on hunting trips.

#### Table A2: Mean income among households with positive income in the respective categories (1000 tzh). Standard deviations are reported in parenthesis. N is the number of observations in the respective sub-samples. Kruskal-Wallis test.

<table>
<thead>
<tr>
<th></th>
<th>Crop¹</th>
<th>Domestic animals²</th>
<th>‘Other’³</th>
<th>Total⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunda</td>
<td>87.85 (122.81)</td>
<td>26.72 (50.24)</td>
<td>73.91 (129.09)</td>
<td>140.88 (171.23)</td>
</tr>
<tr>
<td>N=166</td>
<td>N=122</td>
<td>N=67</td>
<td>N=166</td>
<td></td>
</tr>
<tr>
<td>Serengeti</td>
<td>44.72 (99.37)</td>
<td>43.39 (84.99)</td>
<td>175.19 (261.40)</td>
<td>137.80 (205.15)</td>
</tr>
<tr>
<td>N*=129</td>
<td>N=109</td>
<td>N=43</td>
<td>N=131</td>
<td></td>
</tr>
<tr>
<td>P⁵</td>
<td>0.000</td>
<td>0.005</td>
<td>0.028</td>
<td>0.203</td>
</tr>
<tr>
<td>SRCP</td>
<td>60.39 (96.79)</td>
<td>26.05 (43.48)</td>
<td>73.45 (130.63)</td>
<td>113.24 (135.02)</td>
</tr>
<tr>
<td>N*=147</td>
<td>N=113</td>
<td>N=66</td>
<td>N=148</td>
<td></td>
</tr>
<tr>
<td>Not SRCP</td>
<td>77.53 (130.36)</td>
<td>42.76 (86.42)</td>
<td>173.57 (258.11)</td>
<td>165.62 (224.00)</td>
</tr>
<tr>
<td>N*=148</td>
<td>N=118</td>
<td>N=44</td>
<td>N=149</td>
<td></td>
</tr>
<tr>
<td>P⁵</td>
<td>0.009</td>
<td>0.017</td>
<td>0.210</td>
<td>0.048</td>
</tr>
<tr>
<td>Total</td>
<td>68.99 (114.99)</td>
<td>34.59 (69.21)</td>
<td>113.50 (197.19)</td>
<td>139.52 (186.63)</td>
</tr>
<tr>
<td>N*=295</td>
<td>N=231</td>
<td>N=110</td>
<td>N=297</td>
<td></td>
</tr>
</tbody>
</table>

¹ Here N is the number of respondents in the respective sub-samples reporting that they cultivate land for crop production.
² Here N is the number of respondents in the respective sub-samples reporting that they keep domestic animals.
³ Here N is the number of respondents in the respective sub-samples reporting positive income from other activities than crop production, animal keeping and hunting.
⁴ Here N is the number of respondents in the respective sub-samples.
⁵ P is the observed significance level. The null hypothesis of equal means is rejected for $P \leq 0.05$. 

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Table A3: Data description and descriptive statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>N</th>
<th>Mean (st. dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAT</td>
<td>Kilo game meat bought from SRCP</td>
<td>45</td>
<td>2.20 (0.690)</td>
</tr>
<tr>
<td>L</td>
<td>Acres of land cultivated for crop production in the household</td>
<td>80</td>
<td>6.147 (5.236)</td>
</tr>
<tr>
<td>L_COT</td>
<td>Number of acres cultivated for cotton in the household</td>
<td>75</td>
<td>0.7400 (1.167)</td>
</tr>
<tr>
<td>L_MAI</td>
<td>Number of acres cultivated for maize in the household</td>
<td>75</td>
<td>1.437 (1.807)</td>
</tr>
<tr>
<td>INDEX</td>
<td>Index for the degree of crop production for own consumption [0,1]</td>
<td>72</td>
<td>0.702 (0.168)</td>
</tr>
<tr>
<td>Y</td>
<td>Number of animals in the household</td>
<td>75</td>
<td>13.60 (14.92)</td>
</tr>
<tr>
<td>POULTRY</td>
<td>Number of poultry in the household</td>
<td>75</td>
<td>7.63 (8.69)</td>
</tr>
<tr>
<td>LIVESTOCK</td>
<td>Number of livestock in the household</td>
<td>75</td>
<td>5.97 (12.52)</td>
</tr>
<tr>
<td>DC</td>
<td>Crop damage indicated from 1 (no damage) to 4 (very much damage)</td>
<td>80</td>
<td>3.50 (0.78)</td>
</tr>
<tr>
<td>DY</td>
<td>Poultry/livestock damage indicated from 1 (no damage) to 4 (very much damage)</td>
<td>63</td>
<td>2.37 (1.17)</td>
</tr>
<tr>
<td>OTHER</td>
<td>Income from non-agricultural activities (except hunting) year 2000, 1000 tzh</td>
<td>80</td>
<td>42.51 (112.13)</td>
</tr>
<tr>
<td>M</td>
<td>Household size, number of household members</td>
<td>80</td>
<td>6.09 (3.30)</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Cotton (N=129)</th>
<th>No cotton (N=142)</th>
<th>P*</th>
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</thead>
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<tr>
<td>Crop income</td>
<td>88.37 (85.94)</td>
<td>37.50 (92.56)</td>
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<tr>
<td>Total income**</td>
<td>147.43 (151.01)</td>
<td>125.37 (197.22)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*P is the observed significance level. The null hypothesis of equal means is rejected for P ≤ 0.05
**Total income except income from hunting.
Table A5: Correlation matrix for variables in the equation for hunting effort

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<th></th>
<th>Dep vari</th>
<th>SRCP</th>
<th>Meat SRCP</th>
<th>District</th>
<th>Acre crops</th>
<th>Acre cotton</th>
<th>Acre maize</th>
<th>Index</th>
<th>No. anim</th>
<th>No. poult</th>
<th>No. livestock</th>
<th>Crop damage</th>
<th>Domestic animal damage</th>
<th>Other inc</th>
<th>House memb</th>
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