

# Optimisation of benefits from agriculture and wildlife land uses by wards in CAMPFIRE areas in Zimbabwe

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## Abstract

*To arrest the ongoing ecological disaster in the country, the government of Zimbabwe implemented the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE). Through the CAMPFIRE programme, each ward could benefit from two land uses – agriculture and wildlife. The ward must make a choice on land uses, in other words how much land to allocate to wildlife and how much to agriculture. When a hunting area belongs to one ward, the outcome is desirable; whereas if it belongs to two wards, it becomes complicated. We modelled the two scenarios: Scenario 1 – hunting area belonging to one ward; and Scenario 2 – hunting area shared by two wards. We used Pontryagin's maximum principle to solve the models analytically and to carry out comparative statics. We also applied the results to the study areas using secondary data. The results from the analysis suggest that there is a need to make it mandatory for communities who bear the cost of wildlife management to share in the revenue from wildlife.*

**Key words:** agriculture; hunting area; Pontryagin's maximum principle; rural district council; wildlife

## 1. Introduction

### 1.1 The CAMPFIRE programme

In 1980, Zimbabwe inherited an environmental regulatory framework that gave privileged access to natural resources to certain groups and sectors, while penalising others (Balduş 2009; Roe *et al.* 2009; Machena *et al.* 2017). Rural communities were barred from the consumptive utilisation of certain natural goods through the promotion of preservation rather than the sustainable utilisation of natural resources (Chimhowu 2009). Since these regulations were seen as intrusive in relation to the livelihoods of communities in marginal environments, they were often unpopular, as they were excluding local people from benefiting from the natural resources in their localities. As such, human–wildlife conflicts increased, as local communities felt that the needs or values of wildlife were given priority over their own needs (Balint 2007; Chimhowu 2009). The local people were losing crops, livestock or even life from wild animals without any compensation from the wildlife authorities. Wildlife conservation was being implemented at the expense of rural development (Bond & Frost 2005; Balint & Mashinya 2006). People living in communal areas interfacing with protected areas developed an adverse attitude towards wildlife, killing some wildlife in a self-defence strategy, while illegally exploiting the biodiversity at their disposal (Bond & Frost 2005). Zimbabwean wildlife populations and their habitats were dwindling outside of state-protected areas due to growing human demands on natural resources, while the effective enforcement of conservation legislation was impracticable across most of the country (Chimhowu 2009; Roe *et al.* 2009).

To mitigate the ongoing ecological disaster, the Government of Zimbabwe, through the then Zimbabwean Department of National Parks and Wildlife Management (DNPWM), initiated the Community-based Natural Resource Management Programme (CBNRM) in the late 1980s through amendment to the Parks and Wildlife Act of 1982 (Child 2004; Balint & Mashinya 2006). This resulted in the birth of the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) (Martin 1986). The original concept of CAMPFIRE was conceived in an attempt to stop the rapid destruction of wildlife species within and outside the national parks, and to correct the inequities in dealing with conservation issues (ART 2002; Taylor 2009). CAMPFIRE therefore is about decentralisation, empowerment and the co-management of indigenous resources (Machena *et al.* 2017).

The three objectives of CAMPFIRE are:

- To improve the managerial capacity of the key stakeholders at all levels;
- To improve the well-being of people by providing direct benefits; and
- To manage wildlife and natural resources in rural areas on a sustainable basis.

According to Machena *et al.* (2017), CAMPFIRE is built on the following six principles:

- Benefits from wildlife must be returned directly to the producer communities;
- Producer communities should be small and homogenous;
- Producer communities must be given the full choice of how to spend their money, including both projects and cash payments;
- Rural district councils (RDCs) should keep producer communities fully informed of and involved in CAMPFIRE;
- There is the need for open and competitive marketing;
- Unfair taxation of wildlife should be avoided (the argument is that wildlife should be treated as livestock and not be taxed on the presumption that it brings in more revenue than livestock).

The producer wards in the CAMPFIRE districts are shown in Table 1. Some of the wards share hunting areas. For instance, in Chipinge district there are nine hunting areas but 11 CAMPFIRE producer wards (Table 1), which shows that at least two sets of wards share the same hunting area.

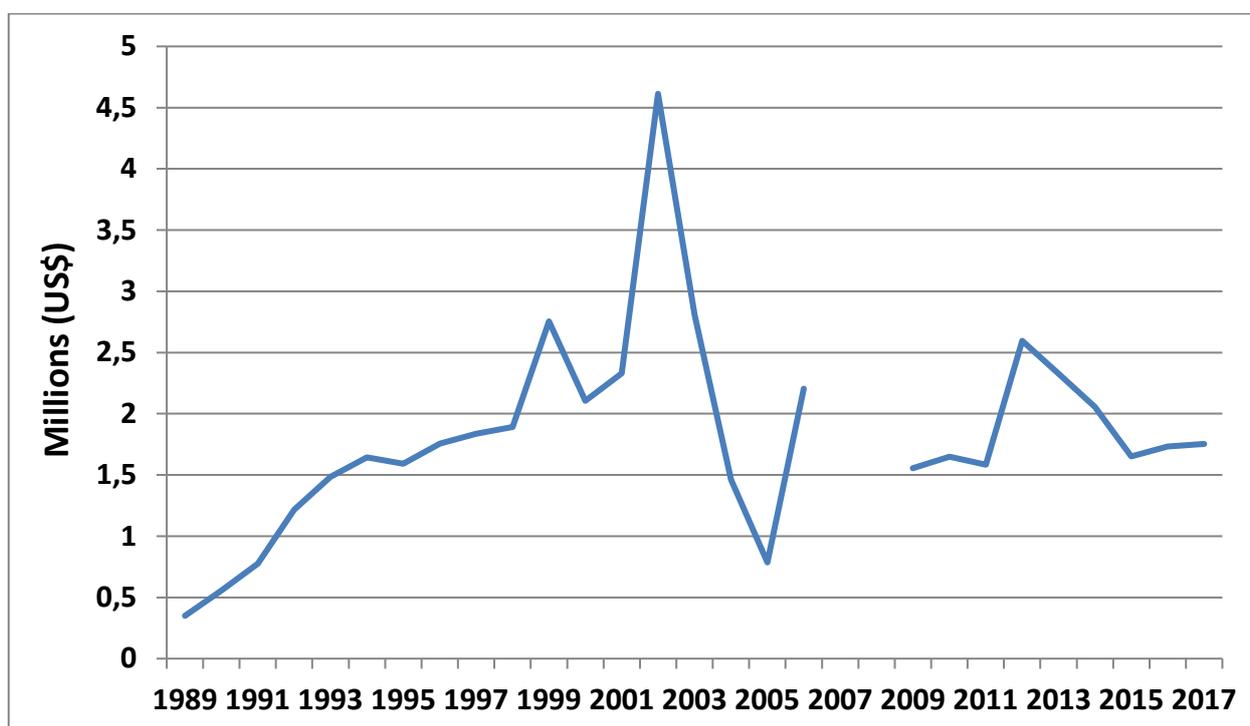
The size of private and communal concession areas in Zimbabwe comprises more than 2.6 million hectares set aside for wildlife conservation, compared to 2.7 million hectares belonging to the public sector (Mazambani & Dembetembe 2010). This shows the contribution of private and communal areas to wildlife conservation in Zimbabwe.

**Table 1: Distribution of wildlife producer wards**

District		Number of wards
1	Beitbridge	7
2	Binga	21
3	Bulilimamangwe	9
4	Chipinge	2
5	Chiredzi	11
6	Gokwe North	14
7	Gokwe South	10
8	Guruve	11
9	Hurungwe	10
10	Hwange	16
11	Muzarabani	14
12	Nyaminyami	12
13	Tsholotsho	9
<b>Total</b>		<b>146</b>

Source: Mazambani & Dembetembe (2010)

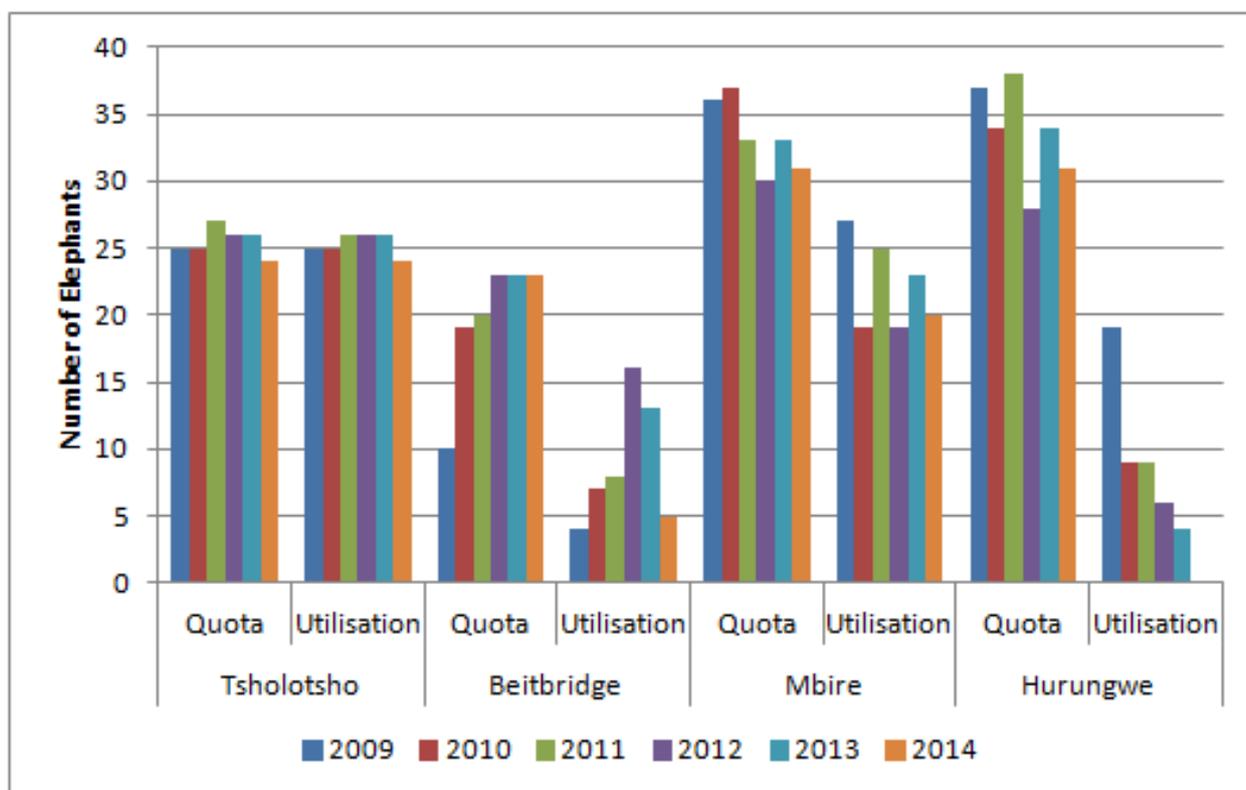
The national revenue from CAMPFIRE is shown in Figure 1. The national CAMPFIRE income increased steadily from the period of inception and peaked in 2002 at just above US\$4.5 million. It decreased sharply in 2005, when it fell below US\$1 million. However, it stabilised to over US\$1.5 million from 2009 until 2017, with a local peak of slightly over US\$2.5 million in 2012. It is essential to indicate that 90% of the CAMPFIRE revenue is from hunting, and 70% is from the hunting of elephants alone (Machena *et al.* 2017).



**Figure 1: National CAMPFIRE income from 1989 to 2017 (data not available for 2007 and 2008 – periods of hyperinflation)**

Source: CAMPFIRE Association (2019)

The utilisation of the elephant-hunting quota in the selected four districts is shown in Figure 2.



**Figure 2: Utilisation of elephant-hunting quota in four CAMPFIRE districts**

Source: Gandiwa *et al.* (2014)

As shown in Figure 2, Tsholotsho district is utilising its elephant-hunting quota fully, unlike the other districts, where there is huge disparity between the quota and the actual number of elephants hunted.

The key institution for the implementation of the CAMPFIRE programme at the grassroots level is the rural district council (RDC), whose power to control the occupation and use of communal areas is legislated in the Rural District Councils Act (ART 2002; Mazambani and Dembetembe 2010), and this power is also usually granted to the appropriate authority under CAMPFIRE. However, it is at the ward level that the wildlife and agriculture management decisions take place.

Through the CAMPFIRE programme, each ward can benefit from two land uses, namely agriculture and wildlife. The ward cannot hunt in the protected areas, but only in the buffer zones. It is from the wildlife in these buffer zones that the ward can benefit through hunting and potentially through tourism. The ward has a choice to make on land uses – that is, how much land to allocate to wildlife and how much to allocate to agriculture. Each CAMPFIRE ward in the district has a hunting (concession) area. However, although a hunting area generally belongs to one ward, in some cases it belongs to several wards. Every year, each hunting area is allocated a hunting quota by a committee led by National Parks, which is granted through the rural district council. The hunting quota is based on several factors, which include the wildlife population in the area, wildlife habitat enhancement, and utilisation of the previous quota. The rural district council, on behalf of the wards, sub-contracts safari operators to hunt on behalf of the wards in each concession area.

According to Machena *et al.* (2017), “the agreed split of CAMPFIRE income (CAMPFIRE Revenue Sharing Guidelines) is that not less than 55% of the revenues is paid as Ward dividends, not more than 26% is allocated to the RDC for wildlife management (habitat management, fire control, monitoring, hiring of game scouts, etc.), 15% is retained by the RDC as an administrative levy, and the CAMPFIRE Association Secretariat gets 4%”.

The hunting revenue at ward level is allocated only to the ward in which wildlife has been hunted. The revenue allocation is straightforward in the case of hunting areas belonging to one ward. It becomes complicated when the hunting area belongs to several wards. In the latter case, this means that, even if the one ward has allocated land for some wildlife, it might fail to get revenue if hunters get the desired wildlife from the “rival” ward, so to speak. There might be competition for wildlife between several wards sharing one hunting area. But at the same time, the wards have to cooperate in terms of hunting area management, otherwise the joint hunting area will be allocated a smaller hunting quota. So, for a ward to have wildlife hunted in its ward area, it has to play an active role to attract the wildlife. This could be done through vegetation and water management, amongst other activities. The policy issue that arises is therefore how several wards should manage one hunting area that they possess together so as to optimise their benefits from both wildlife and agriculture. Another issue is that, even if a ward can decide on its wildlife area – which is a communal area in this case – individual households might not respect this and might continue their agricultural activities in this wildlife area, jeopardising the wildlife benefits (how to manage private and communal land-use decisions). The other policy issues that have arisen from this study are: how to effectively reduce human–wildlife conflicts in areas near protected areas; and how to enhance livelihoods for households living in marginal areas of the country. This paper focuses on the first policy issue.

The major aim of this study was to assess how communities manage/allocate agriculture and wildlife areas in CAMPFIRE wards. We assessed how communities sharing a hunting area can optimally manage their activities so as to maximise their benefits. We used two scenarios: a hunting area that is not shared; and a hunting area shared by two wards.

## 2. Methodology

We made use of used analytical models and scenarios in this study. We used Pontryagin’s maximum principle to solve the models analytically and to carry out comparative statistics. We applied the model to the Mahenye and Mutandahwe wards in Chipinge district to illustrate the effects of sharing a hunting area. The basis of the models is as follows: the model takes as its point of departure the bio-economic model developed by Clark (1973) for fisheries, and further modified by Swanson (1994) for terrestrial conditions. Muchapondwa (2003) and Fischer *et al.* (2005) used the same framework for analysing wildlife management before and after CAMPFIRE. The emphasis was on poaching prevention under communal wildlife management. However, in our models, the issues are about sharing hunting area and benefits between a ward and its “rivalry”. We first solved the model analytically, and then applied the findings to the study areas. We used secondary data from the CAMPFIRE association and other sources to estimate some of the parameters of the models.

The comparison of the project site with other selected CAMPFIRE areas is shown in Table 2. As shown in the table, Hwange has the largest number of CAMPFIRE wards, whilst Chipinge has the smallest number of CAMPFIRE wards. All the CAMPFIRE wards are located in the arid and semi-arid regions, and the sources of livelihoods for the populations are based on marginal crop and livestock production, which makes wildlife an attractive alternative land use (Table 2).

**Table 2: Distribution of wildlife producer communities in the project areas**

District	Number of wards (wards in CAMPFIRE)	Population size	Livelihoods	Area (km <sup>2</sup> )
Chipinge	33 (2)	300 792	Subsistence farming, including growing of small grain, livestock rearing and crafts	5 223
Chiredzi	32 (10)	275 759	Subsistence farming, with growing of small grain and livestock rearing and crafts	4 655
Hwange	20 (19)	132 185	Subsistence agriculture – cropping and livestock	3 769
Mbire	17 (11)	82 380	Drought-tolerant crops such as cotton, millet and sorghum, as well as maize	4 714
Tsholotsho	22 (11)	119 231	Subsistence farming for drought-resistant crops of sorghum and pearl millet, as well as livestock	7 844

### 2.1 Model 1: Hunting area belonging to one ward

We started with a scenario in which a ward can invest in a wildlife habitat so as to attract wildlife, and is able to sell hunting licences, but at the same time lives on agriculture. It therefore has to make a decision about how much land to put under wildlife and how much investment should be allocated to improving the vegetation.

The proportion of land under agriculture is denoted by  $A$  and that under wildlife is denoted by  $W$ . The land base is fixed, so the relationship between agriculture and wildlife land uses is as follows:

$$A + W = 1 \quad (1)$$

We assume that vegetation is homogenous and habitat quality is improved by increasing vegetation biomass, the level of which is denoted by  $V[t]$ , which implies that vegetation is dependent on time. The levels of vegetation biomass today depend on the biomass levels yesterday, and on the community investment in habitat improvement. If we denote habitat investment by  $I(t)$ , we can represent the biomass technology by the function  $g(V[t], I[t])$ , where  $g$  is an increasing function of both vegetation and investment. However, marginal ‘productivity’ decreases as vegetation and investment increase. We assume that  $g_{V[t]}(V[t], I[t]) > 0$ ,  $g_{I[t]}(V[t], I[t]) > 0$ ,  $g_{V[t]V[t]}(V[t], I[t]) < 0$ , and  $g_{I[t]I[t]}(V[t], I[t]) < 0$ . We also assume that there is one grazing species, denoted by  $X[t]$ , the number of animals at time  $t$ . Changes in vegetation biomass are a result of changes in vegetation growth minus herbivore consumption. For notational convenience, we suppress time notation, but time should be understood to be implicit in all the variables. The equation describing vegetation dynamics is:

$$\frac{dV}{dt} = g(V, I) - \beta X, \quad (2)$$

where  $\beta$  represents the rate of vegetation depletion through grazing. Due to computational limitations, we are assuming that each animal consumes a fixed amount of vegetation. This implies that the amount consumed per animal is independent of the vegetation biomass. We are also assuming a non-interactive grazing system, where the herbivore has no influence on vegetation growth other than the removal of vegetation biomass through grazing (Caughley 1976). We have also assumed that vegetation consumption per animal is constant. The herbivore growth rate is dependent on own stock and vegetation biomass, that is, the more the herbivores and vegetation biomass, the higher the growth rate – although this increases at a decreasing rate. The herbivore dynamics are given by the following population dynamics equation:

$$\frac{dX}{dt} = h(X, V, W) - qX, \quad (3)$$

where  $h(X, V, W)$  is the herbivore growth function, which depends on the number of herbivores, vegetation biomass and the amount of land allocated to wildlife. The function  $h$  is an increasing function in herbivores, vegetation and amount of land allocated to wildlife, but does so at a decreasing rate;  $q$  denotes the rate of herbivore offtake. The specifications of the herbivore growth model are as follows:  $h_x(X, V, W) > 0$ ,  $h_v(X, V, W) > 0$ ,  $h_w(X, V, W) > 0$ ,  $h_{xx}(X, V, W) < 0$ ,  $h_{vv}(X, V, W) < 0$ ,  $h_{ww}(X, V, W) < 0$ ,  $h_{xv}(X, V, W) > 0$ ,  $h_{xw}(X, V, W) > 0$ ,  $h_{vw}(X, V, W) > 0$

Given the licences allocated to it by the government through the Department of National Parks, the ward chooses, at each point in time, the amount of area to devote to agriculture and the amount of income to invest in habitat improvement. The ward derives its income from agriculture and selling hunting licences. The number of licences to be bought is dependent on the number of wildlife and the area under wildlife. We assume that hunters will be prepared to buy more hunting licences in a bigger area ( $W$ ), and also to hunt where there are more animals (i.e. where  $X$  is larger). The unit net profit then is an increasing function of  $X$  and  $W$ , but it does so at a decreasing rate. On the other hand, the ward also derives income from producing crops and livestock. The ward's unit net profit function ( $\varepsilon$ ) is given by:

$$\varepsilon = b(X, W)pq + Tf(A) - ZI, \quad (4)$$

where  $b(X, W)p$  is the unit net profit function of wildlife hunting licences, which depends on the wildlife stock and the area under hunting activity. We assume the costs of selling hunting licences, like advertising and communication, are constant and already incorporated in the unit net profit function. On the other hand,  $p$  is the given market price of wildlife offtake, representing the price hunters pay for the right to hunt an animal. The function  $f(A)$  is the matrix of amount of land allocated by the ward to various agricultural crops, and  $T$  is a net profit vector matrix per unit of agricultural land from various ward enterprises. For simplicity, we are assuming one agricultural enterprise.  $Z$  is the unit cost of habitat enhancement.

The ward chooses agricultural production area and habitat investment levels at each point in time to maximise the discounted present value of the net income streams. The maximisation problem is given by:

$$\text{Max}_{W, I} \int_0^{\infty} [b(X, W)pq + Tf(A) - ZI] e^{-rt} dt, \quad (5)$$

where  $r$  is the economic discount rate, with the specification that  $r > 0$ .

The ward can manipulate the wildlife area, and investment in vegetation improvement,  $I$ , to maximise net benefit. We assume that an interior solution exists, thus that there is no need to invoke the Kuhn-Tucker conditions that are required when there is a corner solution (Clark 2005). The maximisation of equation (5) takes place subject to equations (2) and (3), so that the current value Hamiltonian for this problem is as follows:

$$H = b(X, W)pq + Tf(A) - ZI + \lambda[g(V, I) - \beta X] + \mu[h(X, V, W) - qX], \quad (6)$$

where  $\lambda$  and  $\mu$  are the current value costate variables for vegetation and herbivore stocks respectively.

The Pontryagin's necessary conditions for a maximum are as follows:

$$\frac{dH}{dI} = \lambda g_I(V, I) - Z = 0 \quad (7)$$

$$\frac{dH}{dW} = b_W(X, W)pq + \mu h_W(X, V, W) - Tf'(A) = 0 \quad (8)$$

$$-\frac{dH}{dV} = \frac{d\lambda}{dt} - r\lambda \Rightarrow \frac{d\lambda}{dt} = r\lambda - \frac{dH}{dV}, \quad (9)$$

$$\text{where } \frac{dH}{dV} = \lambda g_V(V, I) + \mu h_V(X, V, W). \quad (10)$$

$$-\frac{dH}{dX} = \frac{d\mu}{dt} - r\mu \Rightarrow \frac{d\mu}{dt} = r\mu - \frac{dH}{dX}, \quad (11)$$

$$\text{where } \frac{dH}{dX} = \mu[h_X(X, V, W) - q] + b_X(X, W)pq - \beta\lambda. \quad (12)$$

Differentiating with respect to costate variable  $\lambda$ , and taking into consideration that, at equilibrium,

$$\frac{dH}{d\lambda} = 0,$$

$$\frac{dH}{d\lambda} = g(V, I) - \beta X \Rightarrow \beta = \frac{g(V, I)}{X}. \quad (13)$$

Differentiating with respect to costate variable  $\mu$ , and taking into consideration that, at equilibrium,

$$\frac{dH}{d\mu} = 0,$$

$$\frac{dH}{d\mu} = h(X, V, W) - qX \Rightarrow q = \frac{h(X, V, W)}{X}. \quad (14)$$

Solving equations (7) and (8) for  $\lambda$  and  $\mu$  respectively,

$$\lambda = \frac{Z}{g_I(V, I)} \quad (15)$$

and

$$\mu = \frac{Tf'(A) - b_W(X, W)pq}{h_W(X, V, W)}. \quad (16)$$

We assumed that an equilibrium exists, so that all conditions are met simultaneously. At equilibrium,  $\frac{d\lambda}{dt}$  and  $\frac{d\mu}{dt}$  are equal to zero. This makes equations (9) and (11) equal to zero, solving for  $r$  in both

equations, and substituting for the values for  $\beta$ ,  $q$ ,  $\lambda$  and  $\mu$  with equations (13), (14), (15) and (16) respectively.

## 2.2 Model 2: Hunting area belonging to two wards

In this scenario, we explored the case where the hunting area belongs to two wards. In this scenario, the wards would be sharing the hunting area, but the hunting revenue is allocated only to the ward in which wildlife has been hunted. We will keep things simple and maintain all the equations as in the previous scenario, except for the ward's unit net profit function ( $\varepsilon$ ), which is now given by:

$$\varepsilon = b(X, W)pq\theta + Tf(A) - ZI, \quad (17)$$

where  $\theta$  is the proportion of the unit net profit function of hunting wildlife licences accruing to the ward. We then explore a situation where the wildlife is hunted in the ward area, implying  $\theta = 1$ . We also assessed a situation in which the wildlife was hunted on the rival ward, implying  $\theta = 0$ . We further explored a situation where  $\theta = 0.5$ , regardless of in which area the wildlife has been hunted.

The Hamiltonian function in which wards are sharing hunting area would be:

$$H = b(X, W)pq\theta + Tf(A) - ZI + \lambda[g(V, I) - \beta X] + \mu[h(X, V, W) - qX] \quad (18)$$

## 3. Results

### 3.1 Hunting area belonging to one ward

Based on equation (6), it can be shown (Clark & Munro 1975; Conrad & Clark 1987; Clark 2005) that the optimal harvest strategy will be the one that brings wildlife stock ( $X$ ) to the steady state level – in this scenario,  $X^*$ , given by the modified golden rules (equations 19 and 20).

$$r = g_v(V, I) + \frac{Tg_I((V, I)f'(A)h_v(X, V, W))}{h_w(X, V, W)Z} - \frac{b_w(X, W)h_v(X, V, W)g_I(V, I)pq}{h_w(X, V, W)Z} \quad (19)$$

$$r = h_X(X, V, W) + \frac{h(X, V, W)b_X(X, W)h_W(X, V, W)p}{[Tf'(A) - b_W(X, W)pq]X} - \frac{g(V, I)h_W(X, V, W)Z}{g_I(V, I)[Tf'(A) - b_W(X, W)pq]X} - \frac{h(X, V, W)}{X} \quad (20)$$

The left-hand side of both equations (19) and (20) represents the economic discount rate prevailing in the market. The right-hand side of equations (19) and (20) represents the economic return on vegetation and herbivores respectively (Clark & Munro 1975). The argument is that, for wildlife to be competitive, the economic return on vegetation and the economic return on wildlife must be at least equal to the economic discount rate; and, if wildlife is not competitive, then management would decide to invest elsewhere where it can get higher economic returns (Mwakiwa *et al.* 2016). Predominantly wildlife investments are inadequately economically competitive, which explains why wildlife species in protected areas might be endangered (Barnes 1996; Bulte & Van Kooten 1999; Fleming & Alexander, 2003).

### 3.1.2 Conditions for the model

The conditions for the model are the following:

- Wildlife is more productive than agriculture, which would make community-based wildlife conservation a feasible hedge asset for agricultural production in marginal rural Zimbabwe.

- Wildlife-based conservation is likely to be high only in those rural areas that can sustain sufficient wildlife populations to generate adequate returns from wildlife activities.

### 3.1.3 Economic return on vegetation

Due to the complexity of analytically solving the components of equations (19) and (20), the effect of each component is based only on the sign. The economic return on vegetation (right-hand side of equation (19)) has three components, namely (i)  $g_v(V, I)$ , the marginal productivity, which has a positive effect on the economic return on vegetation; (ii)  $\frac{Tg_I((V, I)f'(A)h_V(X, V, W))}{h_W(X, V, W)Z}$ , the net vegetation herbivore agriculture productivity, which has a positive effect on the economic return on vegetation; and (iii)  $\frac{b_w(X, W)h_V(X, V, W)g_I(V, I)pq}{h_w(X, V, W)Z}$ , the net marginal profit herbivore vegetation productivity, which has a negative effect on the economic return on vegetation.

**Table 3: Comparative statistics – effect of change in the market price of wildlife offtake (p) and the unit cost of habitat enhancement (Z) on the economic return on vegetation (hunting area belonging to one ward)**

	$g_v(V, I)$	$\frac{Tg_I((V, I)f'(A)h_V(X, V, W))}{h_W(X, V, W)Z}$	$-\frac{b_w(X, W)h_V(X, V, W)g_I(V, I)pq}{h_w(X, V, W)Z}$	Overall
p	+	+	-	-/+
Z	-	-	+	-/+

In the model, the price of herbivore offtake and the unit cost of habitat enhancement have direct effects on the economic return on vegetation (equation (19)). The effect of a permanent increase in the price of herbivore offtake on the economic return on vegetation is ambiguous (Table 3). The price of herbivore offtake has a positive (indirect) effect on the marginal productivity, a positive (indirect) effect on vegetation and herbivore productivity, and a negative (direct) effect on the net marginal profit from herbivore and vegetation productivity. If the increase in herbivore offtake results in the rate of increase in the first two terms surpassing the third term, then a permanent increase in the price of herbivore offtake would have a positive effect on the economic return on vegetation. This would imply that the wards would invest more in investment in vegetation quality.

As for the effect of unit cost of habitat enhancement (Z) on the economic return on vegetation to be positive, this will depend on the positive effect of the net marginal profit from herbivore and vegetation productivity dominating the negative effects of the marginal productivity and the vegetation and herbivore productivity (Table 3). This implies that the permanent increase in the cost of habitat enhancement would be beneficial if the effects on the costs do not outperform the effects on the vegetation and herbivore productivity.

### 3.1.4 Economic return on herbivores

The economic return on herbivores (right-hand side of equation (20)) has four components, namely (i)  $h_X(X, V, W)$ , the marginal productivity, which has a positive effect on the economic return on herbivore; (ii)  $\frac{h(X, V, W)b_X(X, W)h_W(X, V, W)p}{[Tf'(A) - b_W(X, W)pq]X}$ , the net vegetation herbivore agriculture productivity, which has a positive effect on the economic return on herbivore; (iii)  $\frac{g(V, I)h_W(X, V, W)Z}{g_I(V, I)[Tf'(A) - b_W(X, W)pq]X}$ , the net marginal profit from herbivore and vegetation productivity, which has a negative effect on the economic return on herbivore; and (iv)  $\frac{h(X, V, W)}{X}$ , the herbivore growth rate:population ratio, which has a negative effect on the economic return on herbivore.

### 3.2 Hunting area belonging to two wards

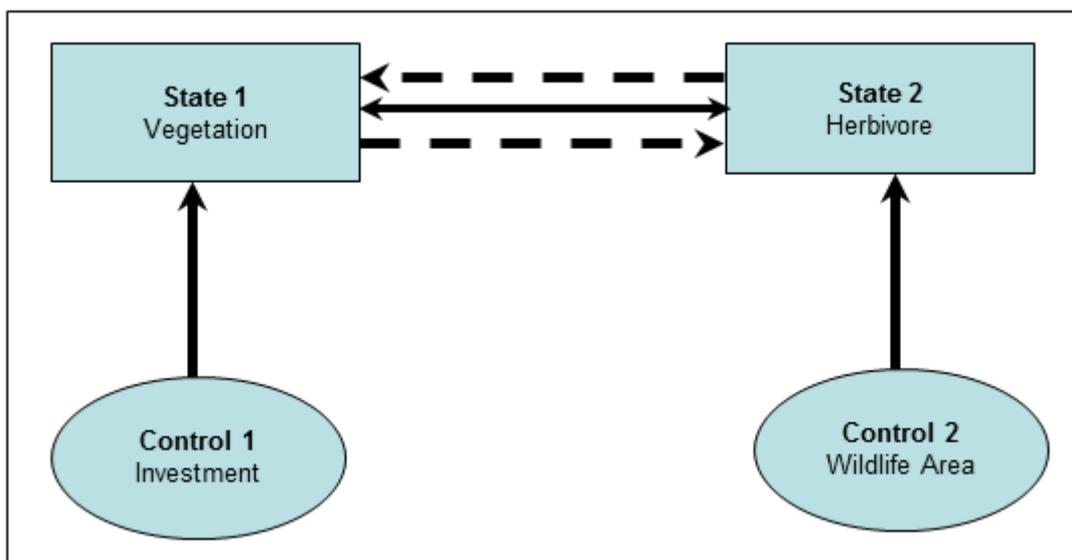
For the scenario in which a hunting area belongs to two wards, the optimal harvest strategy will be the one that brings wildlife stock (X) to the steady-state level in this scenario, X\*, given by the modified golden rules (equations (21) and (22)).

$$r = g_v(V, I) + \frac{Tg_I((V, I)f'(A)h_V(X, V, W))}{h_W(X, V, W)Z} - \frac{b_W(X, W)h_V(X, V, W)g_I(V, I)pq\theta}{h_W(X, V, W)Z} \tag{21}$$

$$r = h_X(X, V, W) + \frac{h(X, V, W)b_X(X, W)h_W(X, V, W)p\theta}{[Tf'(A) - b_W(X, W)pq\theta]X} - \frac{g(V, I)h_W(X, V, W)Z}{g_I(V, I)[Tf'(A) - b_W(X, W)pq\theta]X} - \frac{h(X, V, W)}{X} \tag{22}$$

### 3.3 Implications of the results

In our model, there is a choice of connecting the controls, and also the controls have direct and indirect effects on the states (Figure 3). For example, investment (control 1) has a direct effect on vegetation (state 1) but an indirect effect on herbivores (state 2) through the effect of vegetation on herbivores (Figure 3). Wildlife area has a direct effect on herbivores but an indirect effect on vegetation through the effect of herbivores on vegetation (Figure 3).



**Figure 3: The direct and indirect effects of controls on state variables. Direct effects of control on the respective variables are represented by continuous arrows.**

The landowner could use both controls at the same time, or could choose to use only one. For simplicity, we assume that there is a unique local maximum (Clark 2005). The ward management could use the controls in this way:

$$I = \begin{cases} 0 & \text{if } X < X^* \\ I^* & \text{if } X = X^* \\ \text{Imax} & \text{if } X > X^* \end{cases}$$

$$W = \begin{cases} W \text{ min} & \text{if } X < X^* \\ W^* & \text{if } X = X^* \\ W \text{ max} & \text{if } X > X^* \end{cases}$$

A comparison of the economic return on vegetation for the scenario in which hunting area is not shared and where hunting area is shared by two wards is that, in the former, the net marginal profit from herbivore and vegetation productivity is multiplied by  $\theta$ , with the proportion of the unit net profit function of hunting wildlife licences accruing to the ward. If the wildlife is hunted in the ward, then the proportion is 1, which makes equation (21) the same as equation (19), with the difference being that this ward will share the other costs of management with the “rival” ward but it would reap all the benefits, whilst the rival ward would not benefit at all from the hunting of this wildlife. This would be unfair economically if this particular ward made more investments than the other ward. However, the opposite is true when wildlife is hunted on the “rival” ward’s area, as the ward will not benefit but would share the costs with the rival ward. However, if  $\theta = 0.5$ , both wards will reap the same benefits, but which ward loses depends on which ward invested more than the other.

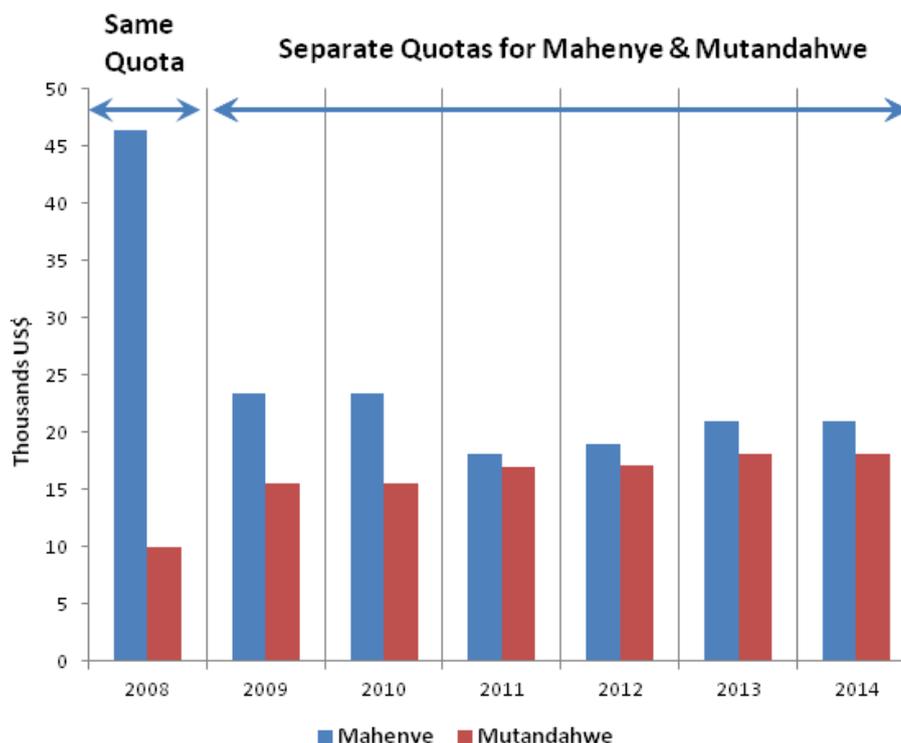
## **4. Discussion**

### **4.1 Policy implications derived from the analytical model**

The real result from this analysis is making it mandatory for communities sharing wildlife to share the revenue from wildlife. If sharing does not happen, the community that is not getting the benefits will find wildlife unattractive, and so will not be willing to allocate their land to wildlife and rather prefer agriculture or any other land use. Another approach to this problem could be to let each ward manage its hunting area by separating the common hunting area, as happened in the Mahenye and Mutandahwe wards in Chipinge. This would allow each ward to have autonomy over the management of the wildlife. This, however, will only apply if the hunting area is big enough and justifies separation.

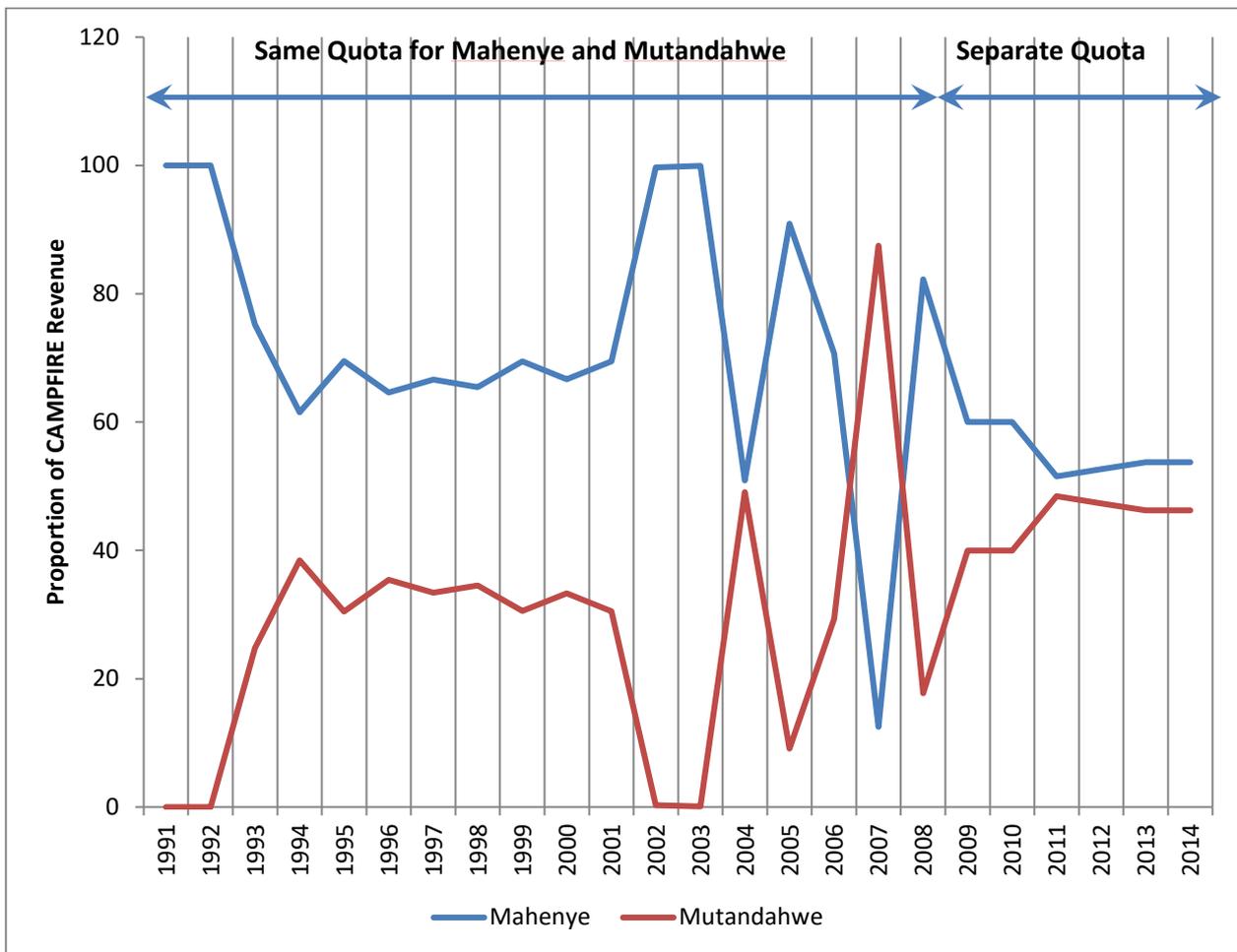
### **4.2 Reference to the analytical model**

For the study area, the results from Chipinge are used, since the wards are in the same locality and they experienced a period in which they shared the same quota and another period in which the quota was separated, thereby closely resembling the scenarios of the models suggested in the analytical part of the paper. These wards are Mahenye and Mutandahwe. Figure 4 shows CAMPFIRE revenue allocated to the Mahenye and Mutandahwe wards from 2008 to 2014. In 2008, these two wards shared the same quota. The periods before 2008 are difficult to compute because of the hyperinflation that affected the Zimbabwe dollar. However, 2008 gives an indication of the disparity between revenue allocated to Mutandahwe and Mahenye, where Mahenye had the upper hand in terms of benefiting. However, when the wards were allocated separate quotas, the disparity in revenue allocation was reduced.

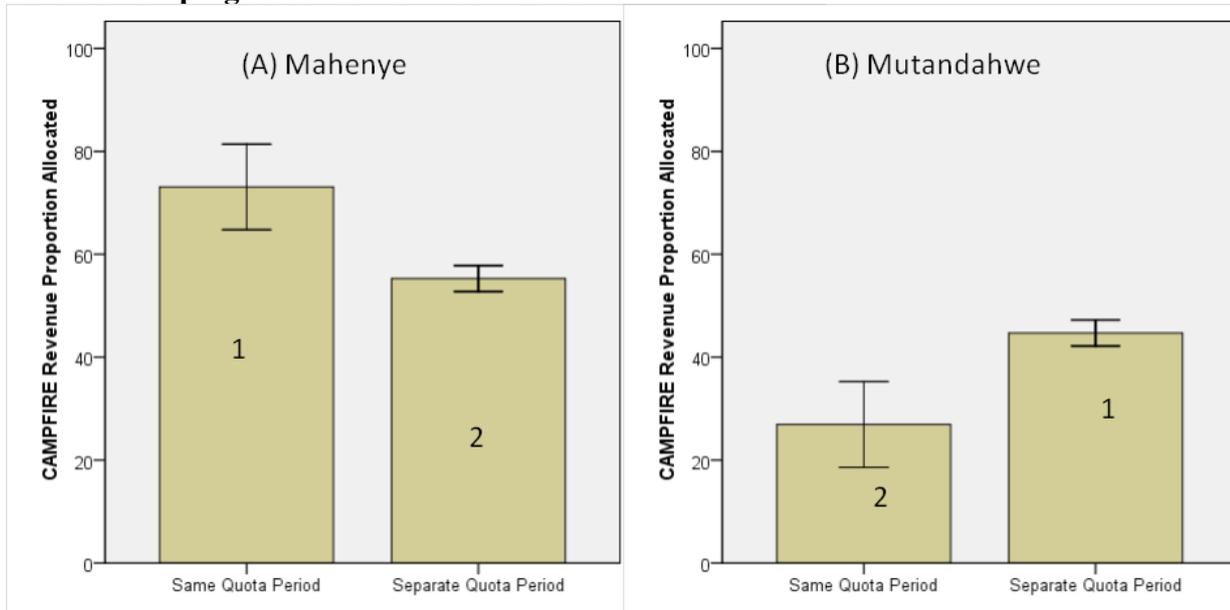


**Figure 4: CAMPFIRE revenue allocated to the Mutandahwe and Mahenye wards of Chipinge district from 2008 to 2014.**

Since it is difficult to perform absolute CAMPFIRE monetary comparisons during the use of the Zimbabwe dollar, especially during the period 2000 to 2007, proportional allocations are used. The gap between the CAMPFIRE revenue proportions allocated to the Mahenye and Mutandahwe wards was very wide in favour of Mahenye during the period when they received the same quota, but was reduced during the period when they received separate quotas (Figure 5). The revenue allocated to the Mahenye ward during the same quota-setting period was significantly higher than it received during the separate quota-setting period, and this was the opposite for the Mutandahwe ward (Figure 6A and Figure 6B). Although the disparity in the proportion of revenue received by Mahenye and Mutandahwe was reduced when the comparison is made for the same quota-setting period and the separate quota-setting period, Mahenye still received a statistically higher proportion than Mutandahwe (Figure 6). Mahenye received more revenue than Mutandahwe under both scenarios because of its proximity to Gonarezhou, the source of elephants. The CAMPFIRE revenue proportion allocated to the Mahenye and Mutandahwe wards, as indicated in Figures 5 and 6, represents the estimate of  $\theta$ , the proportion of the unit net profit function of wildlife hunting licences accruing to the ward as appearing in equations (21) and (22).

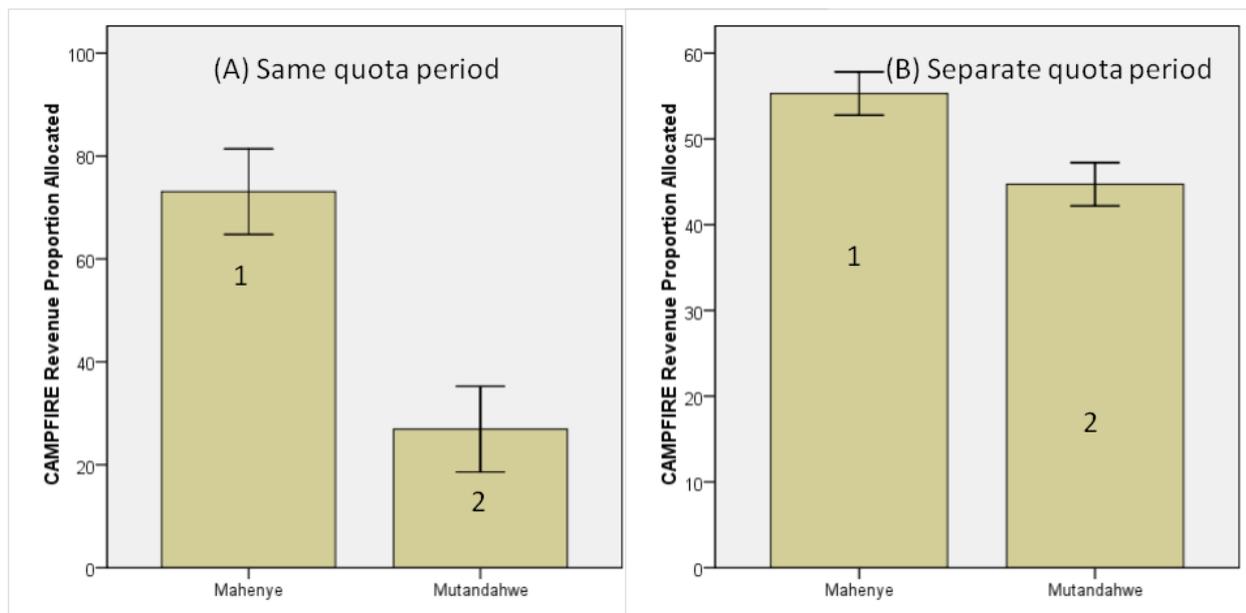


**Figure 5: Proportion of CAMPFIRE revenue allocated to the Mahenye and Mutandahwe wards of Chipinge district from 1991 to 2014.**



**Figure 6: Comparison of proportion of CAMPFIRE revenue allocated to wards during different periods of quota setting. Numbers in bars represents different significant groups in descending order based on the independent samples t-test.**

The differences between the CAMPFIRE revenue proportions allocated to the Mahenye and Mutandahwe wards is greater in the same quota period, but narrower during the separate quota period (Figure 7).



**Figure 7: Comparison of proportion of CAMPFIRE revenue allocated to the Mahenye and Mutandahwe wards during and after the same quota period. Numbers in bars represents different significant groups in descending order based on the independent samples t-test.**

The CAMPFIRE revenue for the Mahenye and Mutandahwe wards shown in Figures 3 to 7 is a proxy for the economic return on herbivores and vegetation as given in equations (21) and (22).

The experience from Chipinge confirms the findings of the analytical model. When the two wards are sharing one hunting area, one ward benefits at the expense of the other. This results in the ward that is left out bearing the brunt of wildlife management, but without much benefit. For the Chipinge wards, the sharing of hunting area resulted in members of the Mutandahwe ward complaining, which eventually led to the separation of the hunting areas. When the hunting areas were separated through the separation of quotas, the gap in revenue was reduced and the Mutandahwe revenue from wildlife increased.

## 5. Conclusions

The model has shown that, for CAMPFIRE revenue to be optimised when there are two wards sharing a hunting area, there is a need for the hunting revenue to be shared between the wards, as long as the wards are also sharing in the management of the hunting area. If one ward is benefiting at the expense of the other ward, the non-benefiting ward might be discouraged from pursuing wildlife management and might pursue other land uses such as agriculture, which in turn will result in a decrease in the hunting area and will eventually lead to a decrease in the wildlife population, and hence in revenue for the benefiting ward. Another approach to this problem could be to let each ward manage its hunting area by separating the hunting areas, as happened in the Mahenye and Mutandahwe wards in Chipinge district. This would allow each ward to have autonomy in relation to the management of the wildlife. This, however, will apply only if there is no social and ecological mismatch, that is, if the hunting areas are big enough when separated. The reason for this is that duiker can be managed at the village level, whilst elephants can only be managed at the ward or even district level. In addition, since Mahenye has more revenue than Mutandahwe under both scenarios – because of its proximity to Gonarezhou, the source of elephants – there might still be a need for some co-operation in sharing the revenue arrangement between the two wards.

## Acknowledgments

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