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Research Article

Reducing rural households' annual income fluctuations due to rainfall variation through diversification of wildlife use: portfolio theory in a case study of south eastern Zimbabwe.

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Abstract
Annual rural incomes in Southern Africa show large rainfall-induced fluctuations. Variable rainfall has serious implications for agro-pastoral activities (crop cultivation and livestock keeping), whereas wildlife and tourism are less affected. The aim of this paper is to investigate the role of wildlife income in reducing rainfall-induced fluctuations in households' annual incomes. We analyse costs and benefits from agro-pastoral systems in southeastern Zimbabwe by means of a two-tier longitudinal survey and wildlife benefits through analysis of wildlife revenues. We use the portfolio theory framework to investigate whether wildlife conservation has the potential for farmers to reduce risk associated with agricultural production. Results show that even though wildlife income is small, it tends to be less volatile than income from the agro-pastoral system. Furthermore, the addition of wildlife as an asset to the rural farmers' portfolio of assets showed that wildlife can be used as a hedge asset to offset risk from agricultural production without compromising on return. The potential of diversification using wildlife is, however, limited since agriculture and wildlife assets are positively correlated. We conclude that revenues from wildlife have some potential to reduce annual household income fluctuations, but only to a limited extent. We argue that if wildlife is organised on a more commercial basis, a more substantial role can be played by wildlife income in reducing variations in rural households' incomes.

Key words: Southeastern Zimbabwe; droughts; portfolio theory; assets; risk.

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Introduction

Most rural households in Sub-Saharan rangelands depend on agro-pastoral land-use activities for their livelihood, combining small scale farming with livestock keeping, or they specialize in herding (pastoralists) or crop cultivation [1]. These households are vulnerable to a wide variety of shocks such as droughts, floods, illness, or localised insect infestation [2]. Such shocks may impose utility losses on households, and reduce the capacity of households or individuals to generate income, mainly because local insurance schemes are absent and monetary savings are too small to act as buffers. Climate-related natural events like droughts are principal sources of risk in savannas. Drought is considered to describe a situation of limited rainfall that is substantially below what has been established to be a "normal" value for the area concerned, leading to adverse consequences on human welfare [3] or loss of physical condition or even mortality among livestock and wildlife. Droughts may induce short-term coping tactics like producing and selling charcoal, thus damaging the resource base and endangering long-term livelihood security [4]. Income fluctuations due to droughts tend to lead to consumption instability or even to starvation [5]. However, income from wildlife utilization often has potential to reduce these fluctuations in income. In sub-Saharan rangelands, high levels of biodiversity still exist, and because wildlife species have evolved with the savanna vegetation [6], they may be better adapted to annual rainfall fluctuations than domestic livestock species.

The 'sustainable use' of wildlife, as opposed to its outright preservation through command and control policies, has a clear economic rationale [7-10], because human appropriation of the land for food supply, infrastructure and other economic developments competes with wildlife [11]. Wildlife needs to be of economic value to local people in order to compete with other land uses. Stripped of its economic value, wildlife cannot compete with other land uses because the competition is too heavily tilted against it [7] and the potential for a conservation relationship between wildlife and local communities is removed. Wildlife is often considered to be a nuisance in terms of disease, crop and livestock predation, and even a danger to human life [12]. Taking economic value away removes added value from wildlife in the form of trophies or for the support of tourism and recreation that make wildlife exploitation economically more attractive than livestock exploitation in a market economy [13]. For example, sustainable use of wildlife more than doubled the land allocated to wildlife in southern Africa by the year 2000 compared to the late 1980s [14, 15], because it has a comparative economic advantage in these environments [16].

Despite claims that African wildlife can generate greater profits than cattle, the relative profitability of extensive cattle and wildlife has not been well established for semi-arid savannas with limited diversity of wildlife [17], especially outside of protected areas. For southeastern Zimbabwe, which receives unreliable annual rainfall below 600mm, Child reported that wildlife alone provides more profit than either cattle or a combination of cattle and wildlife [18]. Economic analysis of community wildlife-use initiatives in Namibia and Botswana have shown that conservancy investments in Namibia and wildlife resources in Botswana are economically efficient and contribute positively to national economic well-being [19-22]. Additionally, data from South Africa confirm that switching to wildlife increased employment five times, the total wage bill 30 times, created numerous upstream and downstream economic multipliers and doubled land values [18, 23]. Wildlife is therefore an important and growing source of income throughout southern Africa under a commercial or ranch set up.

Very few attempts have been made to understand the extent to which wildlife income can complement income in rural households. Most rural Africans live on communal lands, where they are often politically disempowered and administratively alienated from the wild resources upon which they depend [24]. Radeny [25] investigated livelihood choices and income diversification strategies in a traditionally Masai pastoral area of southern Kenya, finding that diversification through cropping was a weak option, with many households not getting a harvest even in a 'good rainfall year'. Instead, households that received wildlife use-related income found it to be a more lucrative option compared to cropping. This implies that wildlife income can potentially complement agro-pastoral incomes for local people in communal systems that show high fluctuations in annual rainfall. The theoretical framework of this paper is based on portfolio theory [26, 27]. Markowitz's original analysis related to financial securities [28], but in this study, under the CAMPFIRE philosophy, rural farmers have an opportunity to acquire income from wildlife conservation as an additional asset. Like agricultural production, wildlife conservation is characterised by uncertainty, but the sources of risk in wildlife conservation are not the same as those to which agricultural production is subjected and the impacts on revenues may differ substantially among the two sources of income [29].This paper builds on a study by Muchapondwa [29] who focused on the theoretical arguments for risk management in agricultural production, by incorporating a more detailed empirical investigation.

In this paper we study how wildlife income can reduce fluctuations in household incomes due to variability in rainfall in a typical savanna system, such as southeastern Zimbabwe. Our main research questions are formulated as follows: (1) What are the costs and benefits associated with agro-pastoral and wildlife systems in southeastern Zimbabwe? (2) How does income from agro-pastoral and wildlife systems vary with fluctuations in rainfall? and (3) To what extent does wildlife income reduce rainfall-induced fluctuations in household incomes?

Methods

Study Area

We focus on the case study area in southeastern Zimbabwe, where wards are sub-district units of local administration covering 150 to 1,000 km^2. The research was conducted in four wards (Chikombedzi, Pahlela, Sengwe and Malipati) within southeastern Zimbabwe (Figure 1), which are part of the Sengwe communal lands. Sengwe, Sangwe and Matibi 2 are the three main communal lands surrounding Gonarezhou National Park (the second largest national park in Zimbabwe). We did not consider Gonakudzingwa in our analysis since the area is under private ownership and the focus of our study is on wildlife benefits under communal set up. The case study area is characterized by low rainfall, shallow soils with low agricultural potential and high temperatures (about 39^{o}C in summer). Annual rainfall ranges between 300 to 600mm. The average rainfall recorded for this area based on 21 year rainfall data (from 1988 till 2008) from Mabalauta section of Gonarezhou National Park was 511 mm. Effective rainfall occurs from October to April, followed by a long dry season.

General framework

To apply the portfolio analysis we need to measure the economic or financial advantages of various activities and their volatility. This requires an economic analysis that focuses on the cost and benefits of particular production units of the activity in question using actual market prices (financial benefits), non-market values or opportunity costs (economic benefits) to value inputs, factors of production, and output [30]. However, comparing peasant agro-pastoral systems by the value of their products is complicated by the fact that many intermediate products and services have no real market [31] and hence no observable market price. We included costs of crop protection in the field and costs of storage. We did not include costs of fertilizer because farmers in the study area do not use fertilisers as soil fertility is not a limiting factor. Labour costs have not been included because the opportunity cost of labour in the region is about zero due to a lack of other productive opportunities. Some factors cannot be easily assessed quantitatively. For instance, the role of livestock in the marriage contract and ceremonial activities cannot be assessed in terms of a quantitative comparison, but should not be ignored either [32]. To deal with these complications we adopt the replacement cost method by Scoones [32], which attempts to value production according to local economic criteria. The economic assessment uses a wide definition of productivity to include both off take (milk, meat) and live animal sales, while services provision (transport, draught) was taken to be an intermediary product.

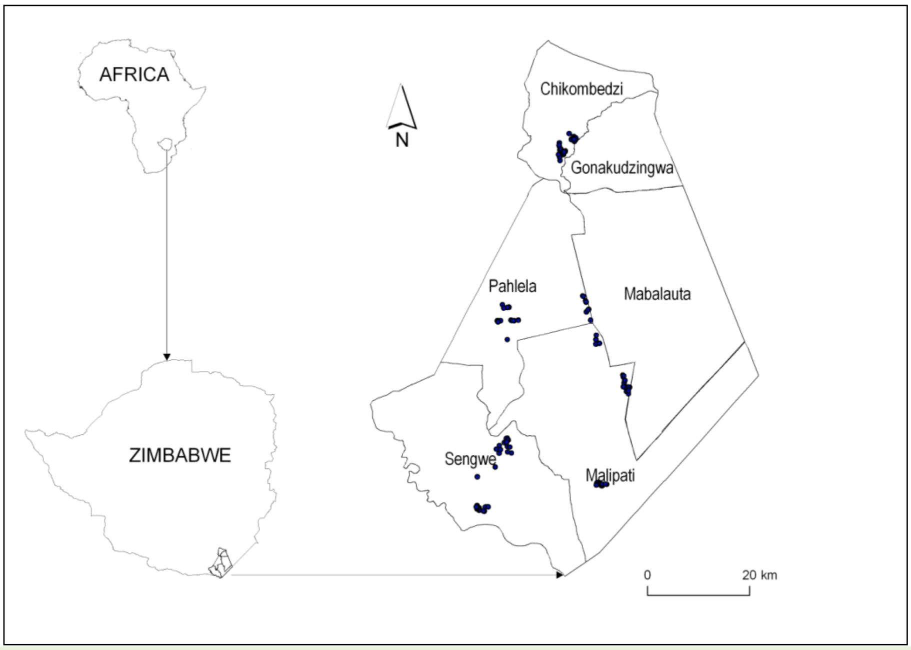


Fig. 1: Study Area (dots indicate positions of sampled villages).

Valuing wildlife using market prices is to some extent possible in southeastern Zimbabwe communal areas. Under the auspices of the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE), communities have created institutions which allow some hunting activities under strict conditions, making it possible for villagers to gain revenues from hunting. This is achieved through the use of services provided by safari operators, who sell hunting quota. In order to obtain information on the direct benefits from wildlife to the local communities, we have assessed the CAMPFIRE revenues given to the communities in two villages: Mutombo and Hlarweni, close to Malipati Safari Area (Figure 1). Under the CAMPFIRE programme [16] the state contracts out hunting concessions to safari operators for an agreed and renewable period. The safari operator buys the right to bring sport hunters and eco-tourists to their concession areas to hunt a set quota of animals, or to track, observe and photograph wildlife. Proceeds from these activities are given to the Rural District Councils, who then make payments to the communities after retaining a levy (38-46%) and also subtracting a percentage which goes to the CAMPFIRE association at national level as a levy (3-4 %). The safari operator pays an annual fee (in hard currency) for the concession (about 30% of the total quota revenues) plus a trophy fee for each animal shot from an annual quota. The quota is the number of animals that annually can be hunted.

In southeastern Zimbabwe, the Department of Agriculture and Extension Services (AGRITEX) assesses crop production twice (mid-season and end of crop growing season) every year. The Veterinary Department also keeps records of cattle dipped per dip tank every two weeks in the dry season and every week in the wet season. These data together with the survey help us in analysing whether household income fluctuates with fluctuations in rainfall from one season to the next.

Data Collection

The research was done using both primary and secondary data sources. Primary sources of data involved a two-tier longitudinal survey of 144 households. The first survey was done in October 2008 during which the area had received below average rainfall (435 mm), i.e., after the 2007/2008 cropping season; and the second in July 2009,when the area had received above average rainfall (681 mm), after the 2008/2009 cropping season. A detailed description of the data collection is given in Appendix 1.

Data Analysis

From the two-tier longitudinal survey, descriptive statistics were used to explore household livelihood strategies and household financial indicators in PASW Statistic v17.0. Kruskal-Wallis tests [33] were used to investigate differences between villages. The survey data allowed calculating costs and benefits from the agro-pastoral system. CAMPFIRE records allowed calculating returns from wildlife systems. To calculate the potential contribution of each system to local people's livelihoods, a detailed comparative economic analysis of the two systems (agro-pastoral and wildlife) was done. This comparative economic analysis involved comparing tangible and intangible benefits and costs from the two production systems. For comparison we calculated the returns for each production system by subtracting total costs from gross benefits. For those tangible benefits and costs that do not have a market or thin market, shadow pricing was employed to express the underlying marginal opportunity cost of goods, services and factors of production.

Calculation of returns per household from wildlife system based on CAMPFIRE revenues was done using three scenarios. The first scenario ('Current scenario') shows communities getting 57 % of the revenues, Rural District council (RDC) taking a levy of 39 % of revenues, with another 4 % going to the National CAMPFIRE association; this represents the current status. The second scenario ('1997 Scenario') shows the revenues which communities would get if the 2008 revenues were to be shared using the 1997 model when communities were getting 78 % of the revenues, the RDC taking 20 % and the CAMPFIRE association taking 2 % of the revenues. The third scenario ('Market Scenario') was calculated assuming the distribution model of the 1997 scenario but based on market prices (data from safari operators) for the animals on the quota, assuming that the costs for hunting (i.e., fuel, food for clients, ammunition, labour, ivory registration) do not exceed 30 % of total wildlife earnings.

A step function was fitted to data from individual wards where cattle population change (Δ_{cattle}) was plotted as a function of average NDVI or total annual rainfall and their lags in R v2.11.0 [34]. This was done in order to test whether income from the agro-pastoral system varies with fluctuations in rainfall, particularly for analysis of livestock. We focused mainly on non-linear relationships between total rainfall and cattle population changes recorded at Pahlela and Malipati dip tanks, where Mutombo and Hlarweni villages dip their cattle respectively. Linear regression was used to estimate the relationship between seasonal rainfall (October to May) and average grain (maize and sorghum) yield from Mutombo and Hlarweni in PASW Statistic v 17.0. We also analysed the potential wildlife revenues based on the price of a species and the respective quota using the 2004 to 2009 quota levels allocated to Malipati safari area. This was done to investigate the response of wildlife revenues to changes in rainfall.

Finally, we investigated whether wildlife conservation is a useful asset for peasants to offset exposure to risk associated with agricultural production. First, we analyzed the returns and risks of wildlife and agro-pastoral on their own. Secondly, we analyzed a portfolio that includes both wildlife and agro-pastoral activities as elements or securities. Historical rainfall data, i.e., from 1988 to 2008 allowed calculation of probabilities of having a bad year (a year with below average rainfall) and a good year. In this study we objectively define drought as the mean rainfall minus one standard deviation or less following Prins [35]. There was a single drought (1991/92) during this period (Figure 2).

In order to match the analysis to the data from the two-tier survey, probabilities of a year with rainfall below the mean (bad year) and one in which rainfall was above the mean (good year) were considered as the two states of rainfall (Figure 2). The returns given the two states of rainfall were taken from the returns (mean for the two villages) reported in Tables 1 and 2. Since Table 2 gives wildlife returns for a bad year, potential wildlife returns from 2009 based on species on quota for that year were considered.

The data allowed for calculation of the expected outcome (returns) and the risk attached to the respective elements and the diversified portfolio, i.e., one which includes both wildlife and agro-pastoral activities as assets for the local people. This was done through calculation of expected returns, variances, standard deviations, coefficient of variation (CV), covariance and correlation coefficient for the two assets independently and combined (See appendix 2 for the calculations).

Results

Household socio-economic and agro-pastoral characteristics

Appendix 3 shows the main household and agro-pastoral characteristics for the eight villages in four wards in southeastern Zimbabwe. Statistically significant ($P < 0.05$) differences between villages for the numbers of cattle (chi-square = 24.004, d.f. = 7, $P < 0.001$), cattle sold (chi-square = 24.800, d.f. = 7, $P < 0.001$), number of donkeys (chi-square = 21.730, d.f. = 7, $P < 0.01$), number of work spans (chi-square = 21.297, d.f. = 7, $P < 0.01$), size of home field areas (chi-square = 31.120, d.f. = 7, $P < 0.0001$), maize and sorghum outputs (chi-square = 58,001, d.f. = 7, $P < 0.0001$) were found.

Mutombo, Hlarweni and Mandamwari are located within 20 km radius of the park boundary and they had lower numbers of cattle and donkeys, and also lower crop yields compared to the other villages. Furthermore, results show that villages that are found close to the park boundary had their food security category classified as transitory, meaning that households got food for seven to ten months in a year, implying a feed gap of between two to five months in a year.

Costs and Benefits of the agro-pastoral and wildlife systems

Returns from agro-pastoral systems were higher in both Mutombo and Hlarweni compared to returns from the wildlife system under the CAMPFIRE program (Tables 1 and 2). Further, it was observed that the annual household returns from the two systems were of similar magnitude for the two villages (US$299 in 2008 and US$1,177 in 2009 for Mutombo and US$446 in 2008 and US$1,081 in 2009 for Hlarweni from agro-pastoral vs. $56 for the two villages from wildlife). Returns from agro-pastoral activities were far much lower in 2008 when the area received below average annual rainfall. Returns from wildlife increased to US$177 under the market scenario.

Table 1 shows that households were getting a significant income from remittances, surpassing net benefits from agro-pastoral activities in a year with below average rainfall (2008), while the remittances were lower in a year classified as good rainfall year (2009).

Table 1. Gross benefits and costs (US $) and remittances (US $)per household for the years 2008 and 2009 from agro-pastoral activities for Mutombo (in Ward 13) and Hlarweni (in Ward 15) villages living close to Gonarezhou National park.

Village		Mutombo		Hlarweni	
Gross Benefits		2008	2009	2008	2009
Livestock	Meat plus Live animal sales	59	18	124	44
	Milk	217	831	265	226
Cropping					
	Maize + Sorghum	30	369	68	906
Total Benefits		306	1,218	457	1,176
Costs					
Livestock	Veterinary	0	0	0	0
	Dip Maintenance	4	4	4	4
Cropping	Crop and grain protection	3	36.9	6.8	90.6
Total Costs		7	40.9	10.8	94.6
Return		299	1,177	446	1,081
Remittances		432	384	621	352

Changes in cattle numbers with variations in annual rainfall

The importance of livestock compared to cropping in southeastern Zimbabwe was shown by the contribution of the two land uses to total benefits from the agro-pastoral system. Table 1 shows that in 2008 income from sale of livestock products (meat and milk) and live animals contributes close to 90 % and 85 % of the total benefits from the agro-pastoral system in Mutombo and Hlarweni villages, respectively.

A step function involves estimation of three parameters: two averages and a threshold. When the two averages are significantly different from each other, it shows the existence of a threshold [36]. The presence of a threshold was confirmed in Pahlela (Threshold, $F_{1,\ 10}$ = 5.59, *P = 0.0397*) and Malipati (Threshold, $F_{1,\ 10}$ = 18.05, *P = 0.0017*) using NDVI as an explanatory factor. However, results from the same study also showed that green vegetation as measured by average NDVI can significantly (*P < 0.05*) be explained by total annual rainfall. This suggests that cattle changes were sensitive to annual fluctuations in rainfall via the direct impact of rainfall on annual forage availability.

Figure 2 shows the changes in numbers of cattle recorded at Pahlela and Malipati dip tanks in relation to annual rainfall. After the severe drought of 1991-1992, cattle numbers went down in both areas, as did the numbers of households owning cattle. These numbers dropped by more than 50 %: from 112 in 1991 to 52 in 1993 for Pahlela and 109 in 1991 to 54 in 1993 for Malipati. After two consecutive years with rainfall below the mean (1994 to 1995), the numbers of animals started a general increase until 2002 for Malipati and 2005 for Pahlela. Figure 2 also shows that the drop in rainfall to below the long-term average (511mm) in 2001 and 2002 and years after 2004 was accompanied by a decline in cattle numbers.

Table 2**.** Returns per household in US$ for 2008 from wildlife system based on CAMPFIRE revenues generated from Malipati Safari and Malipati communal area quota under three scenarios. The first Scenario indicates the current distribution of revenues where communities get 57 %, while the second scenario assumes that communities get 78 % of the revenues (no remittances to Park) as used to happen in 1997. The third shows calculations done based on Market prices for the species on quota (see further the text)

		Scenarios		
		Current Scenario	1997 Scenario	Market Scenario
	Revenue categories			
1	Revenues from Malipati safari offtake	89,903	89,903	153,377
2	Remitted to Park (as owners of Land)	53,590	0	0
3	Revenues from Malipati Communal Area off take	56,493	56,493	56,493
4	Total revenues accrued at RDC (Trophy + Concession Fee) (1 - 2 + 3)	92,806	146,396	209,870
5	Levy (CAMPFIRE Association) (4 and 2 % of 4)	3,712	2,928	4,197
6	Rural District Council (RDC) (39 and 20 % of 4)	36,194	29,279	41,974
7	Community (57 and 78 % of 4)	52,899	114,189	163,699
	Cost categories			
8	Livestock Predation	618	618	618
9	Crop Damage	936	936	936
10	Total costs (8 + 9)	1,554	1,554	1,554
11	Return (7 – 10)	51,345	114,189	162,145
12	Number of beneficiary households	915	915	915
13	Return / Household (11/12) (US$)	56	123	177

Note: Malipati Safari Area belongs to Gonarezhou National Park, but was leased to communities for CAMPFIRE activities hence some of the revenues go back to the owners of the land. This arrangement is different with other CAMPFIRE areas owned by the state through the RDC like Malipati communal area, no revenues would go to Park, and all will go to RDC on behalf of communities.

Variations in crop yields with rainfall fluctuations

In this study returns from agro-pastoral systems were calculated based on a 2 year survey, therefore there was need for us to establish if crop yields were varying from year to year due to fluctuations in rainfall using long term data (10 years). Results from a linear regression analysis showed that seasonal rainfall significantly (Adjusted R^2= 0.49, $F_{1,18}$ = 19.5, $P < 0.001$) explained changes in average maize grain yields and sorghum grain yields (Adjusted R^2= 0.49, $F_{1,18}$ = 17.004, $P < 0.001$) that were estimated from period 2000 to 2009 (Figure 3). The results generally show that maize and sorghum yields for both Mutombo and Hlarweni (Figure 3) decline with a decrease in rainfall. However, the lowest yields for both maize and sorghum in the two villages were not found in lowest rainfall years.

Highest maize and sorghum yields were recorded in year 2000, a year in which the area was hit by cyclone Eline. Two years after the cyclone, the area received the lowest amount of rainfall, therefore we expected lowest yields that year. Perhaps effects of the cyclone, such as raised water table and fertilization (bringing fertile deposits from upstream), caused the yield not to fall to the lowest levels in 2002. Lowest yields were recorded in 2007 due to low amounts of rainfall received in December 2006 and January 2007 resulting in mid season drought.

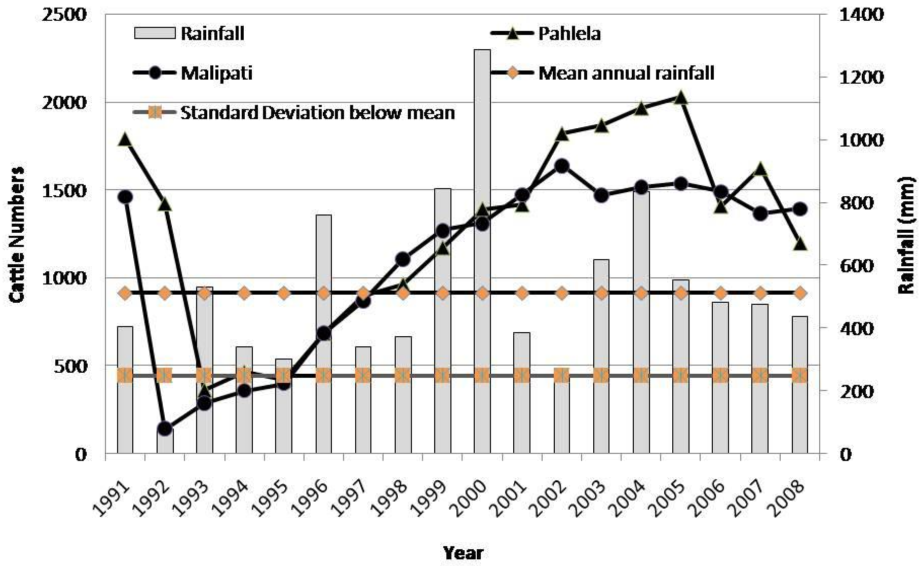


Fig. 2: Changes in numbers of cattle recorded at Malipati and Pahlela dip tanks with variations in annual rainfall.

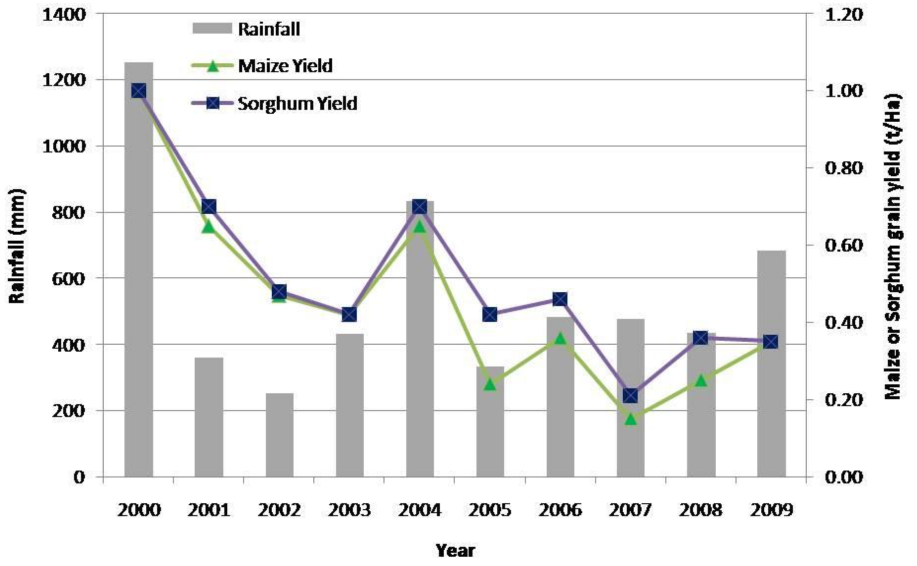
Changes in potential wildlife revenues with fluctuations in rainfall

Based on the returns from the two systems, our study shows that the income from wildlife systems is relatively small compared to the income that can be generated from agro-pastoral systems. Figure 4, however, shows an increase in potential revenues using 2004 to 2009 quota levels that were allocated in the Malipati Safari Area for CAMPFIRE activities. These are referred to as potential wildlife revenues because they are calculated based on the number of different species on the quota for that particular year. In many cases not all animals on quota will be killed, the number depends on the preferences of the hunter. Further, the increase in potential wildlife revenues during this period was against a background of a decline (below the long term average of 511 mm) in annual rainfall from 2006 to 2008, suggesting stability of wildlife income.

Wildlife income as strategy for managing and coping with drought risk

By calculating the expected income of individual assets, it can be observed that the expected income from agriculture is higher than that from wildlife (660 vs. 194) (Table 3). However by diversifying, i.e., adding wildlife income to agricultural income, especially during bad rainfall years, the diversified portfolio gives a much higher expected income compared to the income from the individual assets. The coefficient of variation shows how risky the undertaking is. It gives a measure of the risk per unit of expected return (income) and it provides a more meaningful basis for comparison when the expected returns (income) on the two alternatives are not the same [37, 38]. It can be observed that agriculture is a risky undertaking compared to wildlife, because the coefficient of variation is 0.56 vs. 0.49 (Table 3).

Diversifying using wildlife results in a low coefficient of variation compared to agriculture alone (0.46 vs. 0.56). Therefore, the diversified portfolio results in a higher expected return which is less risky than agriculture alone. The power of diversification can be measured using covariance and correlation. Covariance is a measure of how much two risky assets move in tandem, whereas correlation coefficient (r) is a scale with a value between -1 (perfect negative correlation) and +1 (perfect positive correlation) [37, 38].



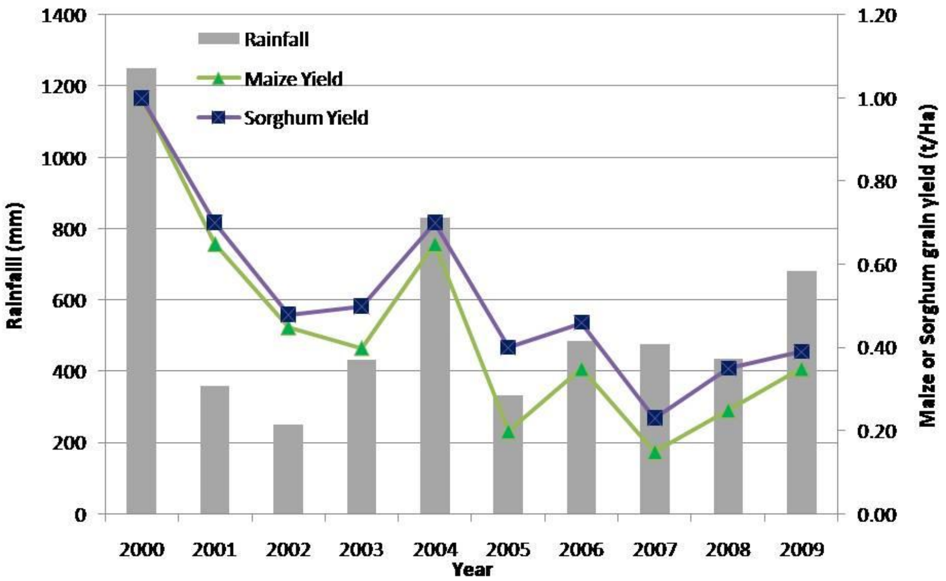


Fig. 3. Changes in maize and sorghum yield (t/ha) with changes in seasonal rainfall (mm) from year 2000 to 2009 for Ward 13 (top graph) and Ward 15 (bottom graph) where Mutombo and Hlarweni villages are located.

Table 3 shows that revenues from agriculture and wildlife are positively correlated (0.4). An investor would prefer assets with negative correlation to those with positive correlation in order to reduce the risk. A weak correlation in this study already allows for exploiting much risk reduction. In the same sense, rural farmers would prefer a negative correlation between agriculture and wildlife for wildlife to provide farmers with a better hedge asset during bad years. However it is clear that the mixed portfolio is less risky than agriculture alone, because the revenues from wildlife are less volatile.

Table 3: Performance in terms of expected incomes and risk attached to different assets (agriculture and wildlife) on their own and as a diversified portfolio.

	Different assets on their own				Diversified portfolio
Assets/securities	Agriculture		Wildlife		Agriculture &Wildlife
States of rainfall	Good	Bad	Good	Bad	
Probability	0.38	0.62	0.38	0.62	
Return (US $)	1,129.00	372.50	222.00	177.00	
Expected Income (US $)		660.00		194.00	854.00
Standard Deviation (σ)		367.00		94.60	389.00
Coefficient of variation (CV)		0.56		0.49	0.46
Correlation coefficient (r)					0.40

Discussion

The results demonstrate the role of wildlife income in reducing rainfall-induced fluctuations in household income and the extent to which wildlife income potentially contributes to local people's livelihoods. Analysis of returns from the agro-pastoral system using survey data for 2008 and 2009 has shown that household incomes fluctuate with variations in annual rainfall. Furthermore, our results have established the higher contribution by livestock income, i.e., from sale of livestock products (meat and milk) and live animals compared to cropping. This agrees with findings from other studies that have shown that households keep livestock for the multiple benefits they provide [39, 40].

Figure 2 indicates the fluctuations that take place in cattle income, which also affects household income as drought causes other households to lose their cattle. Rainfall-induced fluctuations in livestock income lead to household income fluctuations in southeastern Zimbabwe from one year to another. For Mutombo village the contribution of livestock income to total agro-pastoral income was high for both years considered bad (2008) or good (2009), while for Hlarweni village the contribution of livestock income to total agro-pastoral income was higher in a bad (2008) year and lower in a good (2009) rainfall year. This may be a reflection of the presence of an irrigation scheme in Hlarweni, where farmers would produce crops rather than livestock in a good year. In areas where there are no irrigation schemes, as in Mutombo village, livestock contribution to household income is significant even in a good rainfall year. The increase in livestock numbers (Figure 2) in the area suggests that income from agriculture may be unsustainable.

CAMPFIRE was established in the late 1980s with the aim of integrating biodiversity conservation and rural development [16, 41, and 42]. Specifically it promised to boost household incomes through the commercial use of wildlife resources in communal lands [43].

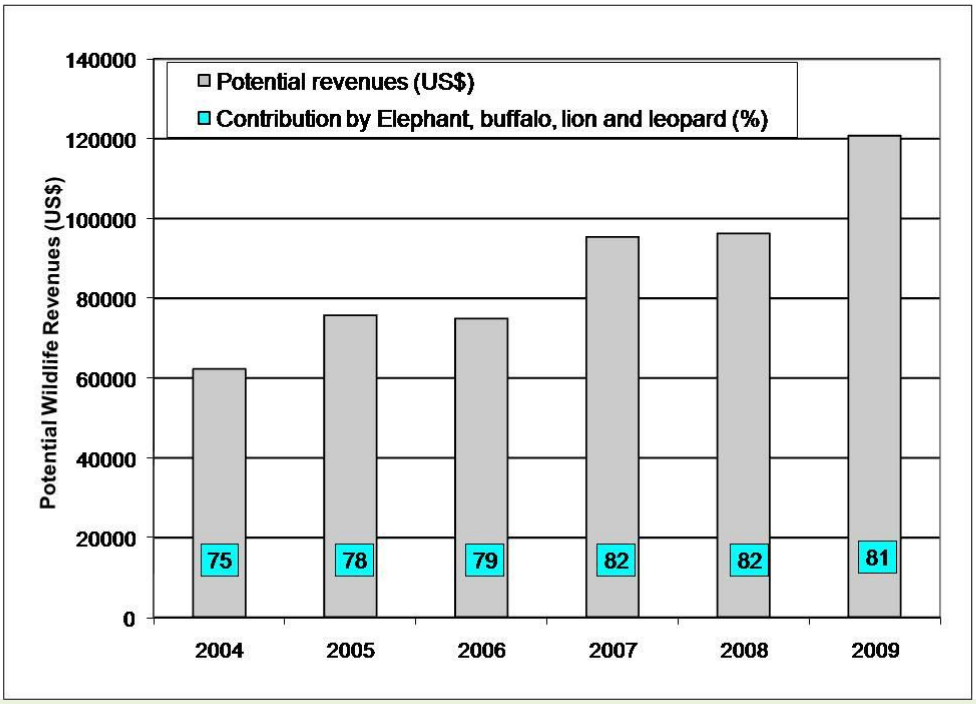


Fig. 4. Potential wildlife revenues (US$) and the level of contribution (%) by the big mammal species based on Malipati Safari Area quota from 2004 to 2009.

However, our results suggest that returns from CAMPFIRE are small compared to income from the agro-pastoral system, making it unlikely that they make a substantial contribution to livelihoods. Table 1 and 2 shows that even if communities were given a greater percentage (equal to what they used to get in the 1990s before the economic downturn in Zimbabwe) the returns still remain small (US$123 vs. US$ 299 in 2008 and $1,177 in 2009 for Mutombo, US$ 446 in 2008 and US$ 1,081 in 2009 for Hlarweni). Our results confirm the outcome of an analysis of CAMPFIRE revenues' contribution to household income in nearby Beitbridge district, which clearly showed that CAMPFIRE revenues made a negligible contribution to household income in southeastern Zimbabwe [43]. The economic downturn that was experienced in Zimbabwe may explain the low wildlife revenues that households and communities receive.

Table 2 shows scenario 2 being much better than scenario 1, perhaps indicating that Rural district council and the Wildlife Authorities were getting a bigger fraction of the wildlife revenues at the expense of rural communities, since the wildlife income was one of the few income sources due to the harsh economic outlook. These findings are consistent with those by Murphree [42] who stated that the long market chains result in communities receiving only a small and inadequate portion of the net revenues. Additionally, Rural District Councils still retain excessive control, especially revenue retention, resulting in the intended primary beneficiaries being severely disadvantaged [44]. Furthermore, these results suggest that if proper pricing of the wildlife resource is done and devolution to communities is completed, as indicated by scenario 3 (Table 3), households may realise better incomes from wildlife. The implementation of the market scenario, however, may not be feasible due to challenges that communities may face namely high costs of entering into safari hunting and management, lack of skills and knowledge by communities of the wildlife market chain at both national and international levels.

Finally, we were interested to know the potential contribution of wildlife income to buffer households against income fluctuations caused by variations in annual rainfall. Portfolio theory [26, 27] was used to investigate how the addition of wildlife as an asset to the usual activities of agricultural production of rural farmers could be used to diversify and subsequently to reduce risk faced by rural farmers [45]. Findings from this study have shown that by exploiting a portfolio that includes wildlife and agriculture, farmers can reduce rainfall-related risk and also improve on the benefits they get (Table 3). This is in agreement with the contention that wildlife conservation is potentially a hedge asset against rainfall-related risk, conveniently at the disposal of rural farmers [29]. Even though wildlife income is small, it has been shown (Table 3) that it is less risky than agriculture and it also forms an important hedge asset to rural farmers during years with low rainfall. Thus rural farmers and conservation managers should not look at the development of individual assets, but at the development of the complete portfolio.

The power of diversification can be measured using covariance and correlation [37, 38]. The investor would be better off in terms of risk by combining assets whose returns are inversely related [38]. Under such cases, the risks of the individual elements cancel each other out as a result of the decrease of the return of one asset being offset by the increase of the return of the other asset. The relationship between the variations in return on the two assets is important because it determines the risk of the complete portfolio [28]. Results have, however, shown a positive correlation coefficient between agriculture and wildlife (Table 3). This finding is not surprising as low rainfall affects both agricultural activities and wildlife, particularly availability of forage or browse. The critical point, of course, is that the correlation coefficient is 0.4 only, thus allowing ample scope for compensatory effects to take place because the impacts of rainfall-related risk on the two enterprises differ, with agricultural production being more vulnerable. The coefficient of variation of agriculture shows that it is more risky than wildlife (Table 3). Theory predicts that systems with many species can buffer the disturbances better than systems with fewer species, because the probability is greater that some species will be able to maintain a certain level of ecosystem service, even though others may fail to function [46, 47]. The diversification effect does not come to bear, however, if the assets follow a completely parallel variation i.e., when agriculture provides more benefit, wildlife provides more benefit too. Risks will not cancel each other out and thus not be reduced by combining the elements in a portfolio [28]. Findings from our study did not show perfect positive correlation and a rather low correlation coefficient (of only 0.4), hence diversification can be possible. Under extreme drought, however, all assets of the portfolio will be exposed to the same risk, termed systemic risk, and these types of risks cannot be diversified.

Implications for conservation

We conclude that people in southeastern Zimbabwe earn a substantial part of their household income from an agro-pastoral system compared to a wildlife system, with livestock income being higher than income from cropping. In dry years agro-pastoral income declines due to livestock losses and lower crop yields. These income losses during dry years are compensated by remittances to a large extent and by wildlife income as these revenues are less sensitive to drought.

Revenues from wildlife have some potential to reduce household income fluctuations due to drought, but only to a limited extent. We argue that if wildlife is organised on a more commercial basis as illustrated by the market scenario, then the net revenues could be increased due to a more efficient and equitable exploitation of the resource potential. Therefore a more substantial role can be played in reducing variations in incomes. The current

CAMPFIRE approach only contributes to a very limited extent to a stable income for rural households. To our knowledge, this is one of the few studies that empirically tested the applicability of portfolio theory to biodiversity related issues. The portfolio theory framework shows that by exploiting different resources of income, rural farmers can realise a more constant household income than by depending on one resource only, because it is rare for the whole portfolio to be affected by risk. This finding could help efforts to conserve wildlife while also improving welfare of local people.

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Appendix 1: Detailed description of data collection

The household formed the basic sampling unit in this study. We adopted and used the definition of a household to mean a group of one or more persons living together under the same roof or in several rooms within the same dwelling, and eating from the same pot or making common provision of food and other living arrangements [1]. The sampling consisted of two villages in each ward surrounding Mabalauta section of Gonarezhou National park. Survey villages and households were selected through a multi-stage sampling procedure. Eight villages (two from each ward) were selected from the wards, resulting in stratified random sampling based on preliminary data from key informants. Stratification was based on population size, number of households, distance from the park boundary, spatial extent of the village, and most common household livelihood activities in the village. The actual questionnaire surveys involved respondents from a randomly selected sample of 156 households in 2008 (ensuring that more than 30 % of the total households in each village were covered) drawn from the village registers. In 2009 the survey covered 144 of the 156 households interviewed in 2008. These 144 households are the same households in 2008 and 2009, in order to capture changes that happen between seasons. Extension workers and village heads helped in visiting and introducing the team of researchers to each respondent and in some cases translating where the respondent preferred speaking in the local language, Shangaan. Household information was gathered on cropping, livestock holdings, numbers of livestock, their classes, age categories, offtake, monetary benefits, and other intangible benefits from livestock as well as the costs incurred in keeping livestock and cropping. The survey also covered crop production interrelationships (draught power, manure and stover from crops), perception of wildlife contribution to household income, and current and past community management systems of animals and natural resources**.** Quantification of livestock and crop predation costs by wildlife was done as part of work reported by Kuvawoga [2].

Secondary data sources used in this study include dip tank records (1991 to 2008)of livestock numbers, their age categories, and numbers moved in and out of each ward, that were obtained from official statistics by the veterinary department [3]. Dip tank counts also showed numbers of animals born, sold and the numbers that died for each particular year. We used dip tank data since cattle dipping is compulsory and also enforced in Zimbabwe as part of a highly controlled cattle husbandry system nation-wide. Data on annual crop yield estimates from southeastern Zimbabwe were obtained from the Department of Agriculture and Extension Services [4]. The crop estimates were obtained through the rural food security assessments by the Zimbabwe Vulnerability Assessment Committee from 2000 to 2009. The average annual grain yields were estimated at the end of the cropping season by averaging yields for 30 farmers in each ward. Other secondary sources of data included data on actual CAMPFIRE revenues generated, payments made to communities and percentages retained by the Rural District Council [5]. The data were obtained from the Rural District Council records. Rural District Council records were also secondary sources for wildlife animal quotas and the actual offtake for the years 2000 to 2009 for Malipati Safari area (hunting area) and Malipati communal area (Appendix 4). The actual offtake would sometimes differ from the quota, particularly for large herbivores like elephants (*Loxodonta africana*), due to problem animal control. Animals not on quota would eventually get killed when they caused crop damage or other problems in surrounding communities. Additionally, Rural District Council records provided information on actual numbers of wildlife animals hunted for trophy by category and their respective revenue values for the same period. These data sources were used to calculate wildlife contribution to household income. Household incomes were calculated for two villages: Mutombo (located in Pahlela) and Hlarweni (located in Malipati) because households from these two wards benefit from CAMPFIRE revenues from Malipati communal and Malipati Safari Area (a 154 km^2 state-owned hunting area under the Department of National Parks and Wildlife Management Authority which has been leased to the community). Further, wildlife data for wildlife animal estimates in the whole park were taken from aerial survey reports [6, 7] that show roughly the densities of wildlife species in the park and the Safari area. For the wildlife densities in the communal area no data were available, but basically in the communal areas the densities are low.

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Appendix 2: Formulas and calculations

Calculation of Expected income (*E* (*I*)) of the different assets:

There are two possible outcomes of rainfall: bad and good rainfall years, and two land uses (assets): Agriculture and wildlife. The probabilities refer to different levels of rainfall: p_g = 0.38 for a good year and p_b= 0.62 for a bad year.

Expected Income (*E* (*I*)) for agriculture and wildlife:

E (I) for agriculture =0 .38 x 1,129 +.62 x 372 = 660;

E (I) for wildlife = 0.38 x 222 + .62 x 177 = 194.

Expected income (*E* (*I*)) for the diversified portfolio:

E (I) for diversified portfolio (agriculture + wildlife) = *E (I)* for agriculture + *E (I)* for wildlife =854

Variance (σ^2) of the expected income:

$$\sigma^2 = P_g[R_g - E(I)]^2 + P_b[R_b - E(I)]^2 \quad (1)$$

Variance (σ^2) for agriculture and wildlife:

Agriculture: σ^2 = .38 $(1{,}129\text{-}660)^2$ + .62 $(372.5\text{-}660)^2$

Wildlife: σ^2 = .38 $(222\text{-}194)^2$ + 0.62 $(177\text{-}194)^2$

Variance σ^2 for diversified portfolio = .38 $((1{,}129+222)\text{-}854)^2$ + .62 $((372.5+177)\text{-}854)^2$

Standard deviation (σ) is calculated as follows:

$$\sigma = \sqrt{\sigma^2} \quad (2)$$

Coefficient of variation (CV) is calculated as below:

$$CV = \frac{\sigma}{E(I)} \quad (3)$$

Covariance of agriculture (a) and wildlife (w) is calculated as follows:

$$Cov_{aw} = \sum p[(R_a - E(I_a))(R_w - E(I_w))] \quad (4)$$

Correlation coefficient is calculated as follows:

$$r_{aw} = \frac{Cov_{aw}}{\sigma_a \sigma_w} \quad (5)$$

Appendix3: Mean household and agro pastoral characteristics (standard deviations in parenthesis) for two villages in each ward

Ward	Chikombedzi		Pahlela		Sengwe		Malipati		
Village	Haisa	Ponyoka	Mutombo	Shavani	Chali	Mudhanisi	Hlarweni	Mandamwari	All
N	21	17	16	20	16	16	19	19	144
Household size	10.00 (5.00)	12.00 (8.00)	9.00 (5.00)	7.00 (4.00)	7.00 (2.00)	8.00 (4.00)	7.00 (3.00)	7.00 (2.00)	8.00 (5.00)
Number of cattle**	7.00 (8.00)	8.00 (17.00)	1.00 (2.00)	11.00 (12.00)	10.00 (14.00)	4.00 (5.00)	3.00 (4.00)	1.00 (2.00)	6.00 (10.00)
Number of cattle sold in 2008**	1.10 (2.30)	0.50 (1.30)	0.13 (0.34)	1.30 (1.80)	0.60 (1.00)	0.56 (1.00)	0.40 (0.80)	0.10 (0.20)	0.60 (1.40)
Number of sheep and goats	7.00 (9.00)	6.00 (7.00)	4.10 (7.00)	7.00 (7.00)	4.00 (8.00)	3.00 (4.00)	8.00 (9.20)	4.00 (5.00)	6.00 (7.00)
Number of sheep and goats sold	0.50 (1.20)	0.30 (0.60)	0.50 (1.00)	0.90 (1.20)	0.40 (1.10)	0.40 (0.80)	0.80 (1.60)	0.30 (0.70)	0.50 (1.10)
Number of donkeys**	0.70 (1.30)	0.40 (1.00)	0.20 (0.80)	1.60 (2.00)	0.90 (2.60)	0.13 (0.50)	0.20 (0.70)	0.40 (1.00)	0.60 (1.00)
Number of work span**	1.00 (0.90)	0.90 (1.00)	0.31 (0.60)	1.40 (1.70)	0.90 (0.90)	0.69 (0.70)	0.50 (0.60)	0.30 (0.50)	0.80 (1.00)
Size of outfield arable area (Ha)	3.70 (4.20)	4.00 (3.00)	2.80 (3.50)	3.00 (2.40)	2.00 (1.90)	4.00 (4.60)	2.40 (2.00)	2.00 (1.40)	2.80 (3.10)
Size of home field arable area (Ha)**	2.00 (4.00)	0	0.70 (1.90)	0.10 (0.40)	0	0.40 (0.80)	0.80 (1.50)	0.08 (0.30)	0.50(1.90)
Maize output 2008 (t)***	0.40 (1.00)	0.50 (1.40)	0.04 (0.04)	0.20 (0.20)	0.20 (0.20)	0.08 (0.09)	0.10 (0.10)	0.05 (0.04)	0.19 (0.60)
Sorghum output 2008 (t)***	0.50 (1.30)	0.50 (1.80)	0.06 (0.04)	0.10 (0.10)	0.01 (0.01)	0.10 (0.14)	0.10 (0.14)	0.03 (0.03)	0.20 (0.80)
Maize output 2009 (t)***	4.50 (10.00)	4.70 (13.00)	0.38 (0.30)	2.10 (2.10)	2.20 (2.10)	0.10 (0.10)	1.20 (1.30)	0.62 (0.66)	2.10 (6.20)
Sorghum output 2009 (t)***	5.30 (13.00)	6.10 (19.00)	0.67 (0.50)	1.30 (1.40)	0.05 (0.10)	1.10 (1.40)	1.40 (1.70)	0.43 (0.37)	2.10 (8.30)
Number of cattle sold in 2009	0.50 (1.00)	0.50 (1.50)	0.10 (0.25)	0.60 (0.80)	0.40 (0.70)	0.50 (0.90)	0.20 (0.40)	0.16 (0.50)	0.10 (0.80)
Food security category	enduring	enduring	transitory	enduring	enduring	transitory	transitory	transitory	

*indicates significant differences between villages at $P < 0.01$ level or better, based on Kruskal-Wallis test.
**indicates significant differences between villages at $P < 0.001$ level or better, based on Kruskal-Wallis test.
***indicates significant differences between villages at $P < 0.0001$ level or better, based on Kruskal-Wallis test.

Appendix 4: Wildlife species quota and offtake and their respective prices from Malipati safari area and Malipati communal area.

	Malipati safari Quota 2004/09						Park Price (US$)	RDC Price (US$)	Market Price (US$)	Malipati safari Offtake 2004/08					Malipati Communal Offtake
Species	2004	2005	2006	2007	2008	2009	2004/09	2004/09	2008	2004	2005	2006	2007	2008	2008
Baboon	10	10	10	10	10	10	5	25	300	2	3	0	1	4	10
Buffalo (M)	2	10	10	10	10	10	1,200	1,500	8,000	2	10	10	10	10	10
Bush buck	0	2	2	2	2	2	400	460	1,075	0	2	2	2	2	0
Crocodile	2	2	1	1	1	2	1,000	1,400	3,000	2	2	1	1	1	2
Duiker	0	2	2	2	2	2	90	100	475	0	2	3	2	2	0
Eland	1	1	1	1	1	1	900	1,035	2,750	0	0	0	0	0	4
Elephant	3	3	3	5	5	6	8,500	9,775	18,000	3	7	3	5	5	3
Elephant (TL)	1	1	1	1	1	1	2,000	2,300	5,950	0	0	0	0	0	0
Francolin	25	25	25	25	25	25	4	4.60	5	0	0	0	0	0	0
Guinea Fowl	25	25	25	25	25	25	4	4.60	5	0	0	0	0	2	0
Impala (F)	10	10	10	10	10	10	40	50	100	10	10	3	5	10	0
Impala (M)	25	25	25	25	25	25	80	100	300	25	25	19	25	25	6
Klipspringer	0	1	1	1	1	1	250	300	600	0	0	1	0	1	0
Kudu (F)	1	1	1	1	1	1	300	330	500	2	1	1	1	0	0
Kudu (M)	5	5	5	5	5	5	600	660	1,000	2	4	2	5	5	0
Leopard (M)	3	3	3	3	3	4	2,500	2,800	3,500	3	1	2	2	3	0
Lion	1	1	1	1	1	2	3,000	3,800	6,500	0	0	0	0	1	0
Nyala	0	0	0	1	2	4	700	875	2,850	0	1	0	1	1	0
Pigeons/Doves	25	25	25	25	25	25	4	4.60	5	0	0	0	0	0	50
Hyena	1	1	1	1	1	1	50	62	450	0	1	1	0	2	10
Sand grouse	25	25	25	25	25	25	3	3.45	5	0	0	0	0	0	0
Water buck	3	3	3	3	3	5	850	1,000	2,000	3	3	3	3	3	0
Zebra	2	2	3	3	3	3	550	600	950	2	2	3	3	1	5
Steenbok	0	0	0	0	0	0	0	110	0	0	0	0	0	0	4
Porcupine	0	0	0	0	0	0	0	22	0	0	0	0	0	0	4

Key: Quota shows the number of animals that the safari company was allowed to hunt/kill that year; Offtake are the animals that were actually killed; M: Male; F: Female; TL: Tusk less