Modelling nature-based tourism impacts on rural development and natural resource conservation in Sikunga Conservancy, Namibia

Steven Gronau, Etti Winter, Ulrike Grote

Abstract

Community Based Natural Resource Management (CBNRM) and nature-based tourism often go hand in hand as a strategy to drive economic development in Sub-Saharan Africa. Yet conservation measures aimed at preserving the resources that tourism thrive on can have negative impacts on the livelihoods of community members. Conversely, if the community continues to unsustainably harvest natural resources, the nature-based tourism sector may collapse, leaving households without an alternative livelihood. Based on survey data of 200 households from 2012, this paper analyses the trade-off between natural resource conservation and development objectives by means of a mathematical programming model that represents the economy of a rural conservancy in Namibia. We find that nature-based tourism may contribute to rural development and sustainable resource management, but only when natural resources are actively protected. We conclude that the tourism sector needs to consider the broader economic and nutritional needs of the community when linking with CBNRM.

Keywords: nature-based tourism; natural resource conservation; CBNRM; mathematical programming; Namibia

1. Introduction

Namibia promotes Community Based Natural Resource Management (CBNRM) via legally established Conservancies with assigned rights to rural communities over the collective management of their natural resources (Lapeyre, 2011). Key components of the program are to improve rural community development through natural resource conservation based in large parts on support of the nature-based tourism sector (NNF, 2013). Tourism's total contribution to Namibia's Gross Domestic Product (GDP) was 15% in 2013, almost 20% of national employment can be attributed to tourism (WTTC, 2014), and about 75% of tourists' expenditure is linked to nature-based activities (Turpie et al., 2010).

Namibia, especially the Zambezi Region, attracts tourists from all over the world. The region is well-known for a variety of fish species, and several lodges have specialised in recreational

fishing, the major contributor to the region's nature-based tourism (Sweeney et al., 2010; Tweddle & Hay, 2012). However, questions remain regarding the degree of community participation in tourism and its compatibility with the existing livelihood system (Tao & Wall, 2008).

The impact of tourism-based activities may generate employment opportunities and conservancy profits amongst its members, which would be positive signs for economic development within conservancies (Bandyopadhyay et al., 2009; Silva & Mosimane, 2012). Thus, rural communities have an incentive to manage their resources sustainably to derive an economic benefit from nature-based tourism (Stronza & Gordillo, 2008). However, the region's attractiveness for tourism is conflicting with community's overexploitation of their natural resources, such as fish.

Furthermore, despite economic growth in the region, food security is a concern in many rural communities in Namibia (FAO, 2015). Fish resources considerably contribute to livelihoods in the Zambezi region. However, increased commercialisation, widespread use of illegal destructive fishing methods, and a lack of resource management led to over-exploitation, putting rural livelihoods and the important regional nature-based angling tourism at risk. This highlights the need to find sustainable solutions to the region's fish resource use (Abbott & Campbell, 2009; Koekemoer, 2003; Naesje et al., 2002; Turpie et al., 2005; Tweddle et al., 2015).

This raises the questions: (i) Does nature-based tourism have the potential to reduce overfishing? (ii) What is the value of nature-based tourism compared to other livelihood strategies?

The remainder of this paper is structured as follows: section 2 reviews literature on nature-based tourism's impacts on rural development and natural resources. Section 3 describes the study area and data collection procedure. In Section 4 the mathematical programming model is explained. Simulation results are shown in Section 5, and Section 6 summarises and concludes.

2. Literature review
Several studies show that nature-based tourism is often seen as a driver of rural development (Fisher & Treg, 2007; Lindsey et al., 2005; Stronza & Gordillo, 2008; Zeppel, 2006).

However, there are growing concerns regarding the impact of nature-based tourism on natural resources in developing countries (Brooks et al., 2006; Nash, 2009; Sims, 2010; West, 2008).

Income from nature-based tourism has helped to diversify livelihoods and income sources for rural households across developing countries (Haggblade et al., 2007; Lapeyre, 2011; Lepper & Schroenn, 2010; Liu et al., 2012; Mbaiwa & Stronza, 2010; Stronza, 2010). Mbaiwa and Stronza (2010) pointed out that the benefits from nature-based tourism within a CBNRM program are just small in absolute terms, but still play an important role in increasing the means of living in rural communities relative to a benchmark situation. Furthermore it can also help improve food security via increased off-farm employment (Babatunde & Qaim, 2010; Owusu et al., 2011). However, even if tourism is integrated into a rural community, traditional sources of income can remain more important, such as crop and livestock production as well as forest extraction (Liu et al., 2012).

Research also critiques the unequal distribution of benefit sharing from tourism among local communities and their contribution to nature conservation (Arjunan et al., 2006; Bandyopadhayay & Tembo, 2010; Kanapaux & Child, 2011; Waylen et al., 2009). The number of people who cannot secure jobs or other benefits from tourism could be significantly larger than the number who can, creating the potential for resentment and consumptive land-use practices (Vanderpost, 2006).

In this context, rural communities often fail to manage scarce resources in a sustainable way and over-utilisation of natural resources has been the norm (Abbott & Campbell, 2009; Fennell, 2008). This remains true in the Namibian context as well, despite the existence of CBNRM and nature-based tourism (Koekemoer, 2003; Naesje et al., 2002; Turpie et al., 2005; Tweddle et al., 2015).

Existing research relies on diverse quantitative and qualitative methods, however there are few studies aiming to explore and quantify the trade-offs between nature-based tourism, rural development and natural resource conservation. The analysis of trade-offs is largely made possible via mathematical programming (Hazell & Norton, 1986; Kaiser & Messer, 2011), which to our knowledge has not been applied in the context of CBNRM to date.

Mathematical programming models have been used on diverse issues such as livelihood analysis, human nutrition and natural resource management (Conrad et al., 2012; Gladwin et

al., 2001; Maruod et al., 2013; Orsi et al., 2011; Tesso et al., 2013; Winter et al., 2015). The contribution of this paper is to construct a mathematical programming tool to simulate resource and tourism conflicts in a CBNRM context. The analysis contributes to existing literature by looking at the linkages between nature-based tourism, rural development as well as natural resource conservation.

3. Data
3.1 Study area
The Sikunga Conservancy is located in the Zambezi region, one of Namibia's poorest regions (Figure 1) (NSA, 2012). Recently, off-farm jobs, in tourism as well as other sectors, have increased in the area (Suich, 2010). Nevertheless, most rural households still depend on subsistence agriculture and natural resource extraction, supplemented by remittances and social welfare payments. Table 1 shows the average sources of income of a Sikunga household. Values are reported in Namibian Dollars where NAD$ 1.00 is roughly PPP$0.60 (WB, 2015).
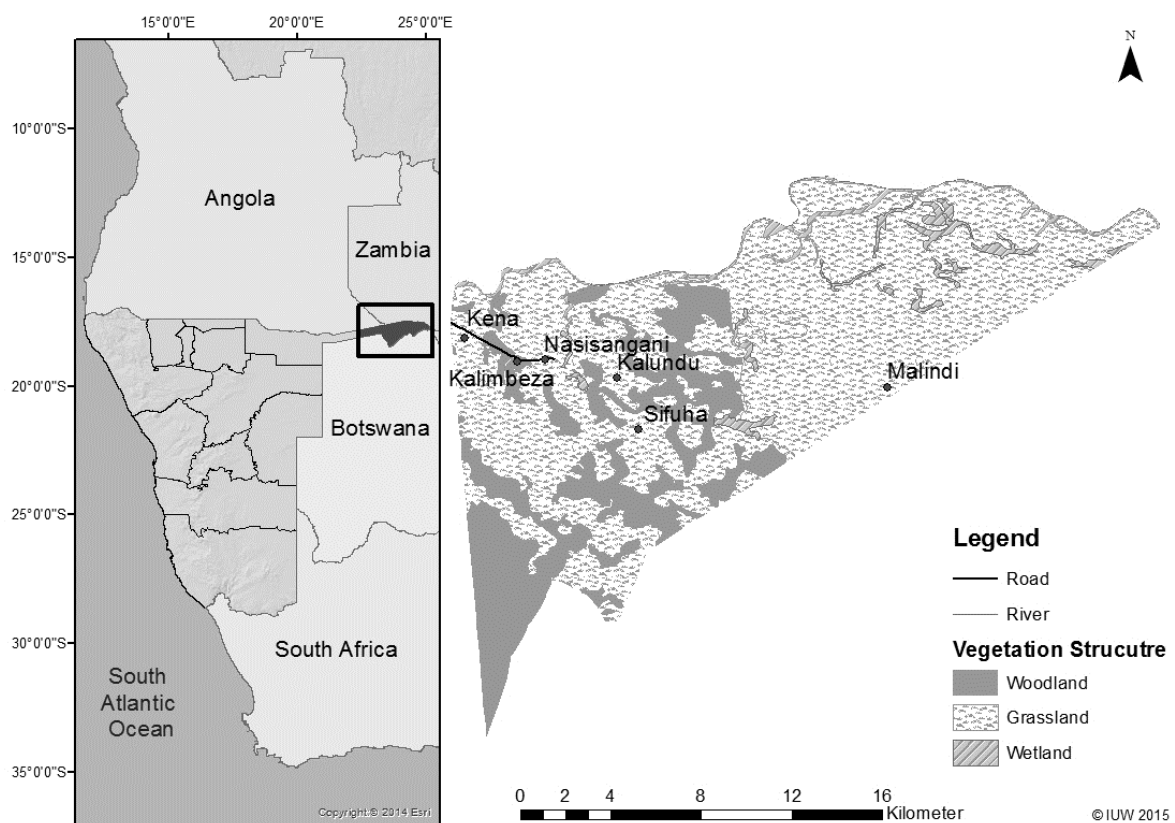
Figure 1: **The Sikunga Conservany in the Zambezi Region, Namibia.**

Source: Author

4

	Household
Number of household members	4.65
	Annual household expenditure (NAD$)
Expenditure on consumption goods	$10 354
	On-farm income (NAD$)
Net income from maize	$591
Net income from livestock	$2 244
	Income from natural resources (NAD$)
Net income fish	$3 830
% Fish sold	15.5%
Income from timber products	$2 641
% Timber products sold	0.8%
	Off-farm income (NAD$)
Off-farm income	$10 960
	Transfers (NAD$)
Annual benefit	$2 790
	Remittances (NAD$)
Annual receive	$1 415
	Total income (NAD$)
Total income	$24 471

Table 1:   A household's average sources of income in the Sikunga Conservancy.
Source: Author.

The topographically flat area has a semi-arid climate with a mean temperature of about 22°C and a highly variable annual rainfall, with 550 mm on average (Mendelsohn et al., 2006). The natural environment consists of grassland, floodplains, and Mopane woodlands in the north (Mendelsohn et al., 2006). The area is well-known for recreational fishing and therefore attracts tourists from all over the world (Sweeney et al., 2010; Tweddle & Hay, 2012). Sikunga was gazetted as a communal conservancy in 2009. The primary objective, as stated in the constitution, is to enable its inhabitants to derive benefits from the sustainable management and utilisation of nature and wildlife in the conservancy. Sikunga is located 60 km east of the regional capital, covering an area of 28 700 ha, with approximately 440 households (around 2400 inhabitants) living in six villages. The conservancy hosts three tourism lodges (NASCO, 2009; NNF, 2013).

Fish stocks in the Zambezi River and across seasonal floodplains are heavily exploited and lack coordinated management (Abbott & Campbell, 2009; Koekemoer, 2003; Naesje et al., 2002; Turpie et al., 2005). The lack of alternative livelihoods for rural communities is blamed as one reason for continued fishing despite dwindling resources (Tweddle et al., 2015). Additionally, community forest resources are generally undervalued, with few controls placed on timber and firewood extraction (Barnes et al., 2010; Parviainen, 2012). Food security is a national concern with 42% of Namibia's population being undernourished (FAO, 2015).

3.2 Data Collection

For the primary data collection, 200 households, around 45% of total Sikunga households, were randomly sampled. A household was defined as conservancy residents who shared the same roof. As sampling was non-stratified, results reflect the full population of Sikunga. A structured survey was used to interview the households in 2012, targeting the household head, and covering all economic activities, including income sources, time-use, consumption and expenditure data, use of natural resources, livestock and crop management, and households' socio-demographics and social capital. Secondary data sources were also used to complete information gaps from the primary data. This information was generally used to calculate environmental stocks and growth rates. Additionally, informal interviews with the conservancy management, lodge operators and local farmers provided meaningful regional insights.

4. The mathematical programming model
4.1 Structure of the model

We developed a model which is used to analyse the complex livelihood system of a rural community. Mathematical programming models can handle the multiple activities undertaken by a set of linear and non-linear equations. It is appropriate for problems related to efficient utilisation of scarce resources and balancing trade-offs where multiple activities compete for the same resources (Hazell & Norton, 1986; Kaiser & Messer, 2011).

Referring to the theoretical framework by Lipton (1968), 'The theory of the optimising peasant', the objective function assumes that households optimise their collective wellbeing subject to a range of constraints and requirements representing the limits of local resources, techniques and capabilities. In the model, each activity competes for scarce resources; thus

the selection of one activity may result in others being excluded from the resources, reflecting the opportunity costs incurred.

The model can be utilised to simulate the impacts of changes in the system on different agents and the environment. It simplifies a multi-objective management problem and can be seen as a central planning tool to determine resource allocation that maximises the social welfare of the Sikunga Conservancy. Alternatively, the aggregated optimisation simulation strategy can be interpreted as simulating the outcome of a cooperative game, where individual households form a grand coalition (Britz et al., 2013). The analogy of the cooperative game with a grand coalition suits the CBNRM concept, which is based on cooperation of community members as well as on collective (community) capacity (Fabricius & Collins, 2007; Mukwada & Manatsa, 2012).

The model has been constructed using the General Algebraic Modeling System (GAMS) Software[1]. Parameters derived mainly from primary data are supplemented by secondary data. As seasonality of available resources is essential, model activities and constraints are specified per month.

The mathematical formulation of the model is as follows:

$$\text{Maximise:} \quad Z = \sum_{h=1}^{200} \sum_{j=1}^{n} \sum_{t=1}^{12} p_j X_{hjt} - \sum_{h=1}^{200} \sum_{j=1}^{n} \sum_{t=1}^{12} c_j X_{hjt} \tag{1}$$

Subject to:

$$\sum_{h=1}^{200} \sum_{j=1}^{n} a_{ijt} X_{hjt} \leq b_{it} \tag{2}$$

$$\sum_{h=1}^{200} \sum_{j=1}^{n} d_{gjt} X_{hjt} \geq e_{gt} \tag{3}$$

$$X_{hjt} \geq 0 \tag{4}$$

$i = 1 \text{ to } m, \quad g = 1 \text{ to } l, \quad j = 1 \text{ to } n, \quad h = 1 \text{ to } 200, \quad t = 1 \text{ to } 12$

---

[1] GAMS is designed for the construction and solution of large and complex mathematical programming models. Various kinds of economic models including linear and non-linear optimisation as well as equilibrium modelling can be solved using GAMS. Revealed marginal values (shadow prices) by programming runs are a special software feature (Brooke et al., 1992).

Where: Z = Community's social welfare maximum from all activities in one year.

X_{hjt} = Level of the activity j, in month t, by household h; decision variable.

p_j = Price of a unit of the activity j.

c_j = Cost of a unit of the activity j.

a_{ijt} = Amount of an input i needed to operate activity j in month t.

b_{it} = Available supply of the resource i in month t.

d_{gjt} = Amount of food or natural resource g needed for activity j in month t.

e_{gt} = Minimum demand levels of food or natural resource g in month t to meet basic needs.

In line with the community's livelihood system, activities included in the model are crop farming, fishing, livestock and milk production, harvesting of forest resources (firewood, thatching grass and reeds), expenditures on food items and natural resource products, hiring labour, tourism employment and other off-farm activities. All activities are based on observations and data from the study area. Modelled households can be involved in more than one of each of these activities at different times of the year and to different levels of intensity. Therefore sources of income can vary in each month as the activity mix changes throughout the year. For rural communities, such as in the Zambezi Region, seasonality is of high importance for their time allocation (Kamwi et al., 2015) and research is needed to assess seasonal changes in livelihoods (Fiorella, et al., 2014). In this context, a special feature and contribution of the model is its construction on a monthly basis, which allows for seasonal analysis. Thus the model allows households to change activities subject to climatic conditions in wet (October to February), flood (March to May) and dry (June to September) season, in an area which is highly susceptible to the seasonality.

Boundaries on the households' resource allocation are created via constraints and minimum requirements, comparable to Gladwin et al. (2001), Maruod et al. (2013) and Tesso et al. (2013). Constraints state that the total use of a resource cannot exceed its availability. They are defined for labour, livestock and milk production, farm-, wood-, grass- and wetland and off-farm activities. Minimum requirements must be met by exceeding at least a minimum level; comprising cash, nutrition and forest resource needs. Regarding cropping, livestock and milk production, fishing and forest resources, the model gives households the choice to use outputs either for subsistence consumption and/or for marketing.

4.2 Model activities

Cropping activities use farmland at the disposal of the households. Operations can be undertaken by manual hoeing and/or by using oxen to plough. The model is sensitive to field preparation, weeding and harvesting period. Livestock (cattle) is largely grazed in open access grassland and forest areas. Milk production depends on the number of cows available, their lactation length, contribution to calves, varying productivity and adequate grazing land. Fishing depends on seasonally varying labour productivity and access rights, and forest products are collected and harvested in open access wood-, grass- and wetland areas.

Off-farm activities are located in- and outside Sikunga. Tourism lodges in Sikunga attract angling tourists, while at the same time offer employment for the rural community. The model distinguishes different job types (manager, skilled, unskilled, part-time and fishing guide labour) limited to observed job market demand.

4.3 Model constraints and requirements

Households' food, natural resource, health and farm input (seeds, labour, etc.) needs can be met either by subsistence production and/or obtained from the market. Because of high malnutrition in rural communities, the challenge for research and implementation is to bridge the gap between livelihoods and nutrition for the benefit of improving food security on community level (Guzman et al., 2015). There is a need for better measurement of economic and sustainability trade-offs regarding nutrition and health (Herforth et al., 2014). A special attribute of the model is thus the nutritional minimum requirements defined for energy, protein, fat, Vitamin A, iron and iodine which makes it sensitive to the availability and stability of regional food items[2].

4.4 Model simulations

We model two scenarios, one where the management of natural resources is weak, and households can extract and harvest natural resources so as to maximise their welfare. In the second scenario, we implement a constraint on natural resource use, so as to protect the nature-based tourism sector and explore changes in livelihood allocation, income, and values of natural resources. In line with the programs goals to improve livelihoods as well as nutrition within CBNRM (USAID, 2013; Vernooy et al., 2009), we also include nutritional requirements.

---

[2] The selection took into account some of the most essential macro- and micronutrients (WFP, 2015).

As highlighted in the previous sections, CBNRM aims to balance economic growth with sustainable natural resource management, yet in our case study area, fish stocks are not being sustainably managed, and income from nature-based tourism is at risk. Our model seekds to balance this trade-offs, which is possible via mathematical programming (Hazell & Norton, 1986; Kaiser & Messer, 2011). Recreational fishing relies on healthy fish stocks and operates with minimum consumptive use; captured fishes are normally released by tourists at rates of around 90% (Sweeney et al., 2010). Due to the Conservancy's high dependence on fish resources, both for consumptive use as well as non-consumptive use by the recreational fishing tourism, the second simulation puts the model world under the umbrella of sustainably managed CBNRM. For this purpose, our model incorporates a biological growth function that calculates the sustainable fish harvesting quantity (Clark, 2006). Including overall sustainability criteria, which also include food security, the model determines the allocation of scarce fish resources by considering (i) nature-based angling tourism as a means to generate income and improve conservation management and (ii) minimum nutrition needs. The scenario thus connects nature-based tourism with the CBNRM concept for improving rural development and natural resource conservation.

The fish stock in the CBNRM scenario is represented by a biological growth function (Equation 5) following Clark (2006):

$$G_{iy} = F_{iy} * r_i * \left(1 - \frac{F_{iy}}{k_i}\right), \qquad\qquad i = 1, \qquad y = 0 \qquad (5)$$

Where: $\quad G_{iy}$ = Annual net growth of the fish resource i in year y.

$\qquad\qquad F_{iy}$ = State of the fish resource i at time step y.

$\qquad\qquad r_i$ = Growth rate of fish.

$\qquad\qquad k_i$ = Carrying capacity of the ecosystem.

Calculations are made for one year (y = 0). Total extraction may not exceed annual sustainable fish harvest level S (steady-state equivalent point) (Equation 6).

$$\sum_{h=1}^{200} \sum_{j=1}^{2} \sum_{t=1}^{12} a_{ijt} X_{hjt} \leq S_{iy} \qquad\qquad (6)$$

Total extraction is the sum of fish caught by all households of the community and by the recreational fishing lodges (consumptive use) within one year. Equation 7 calculates the state of the resource.

$$F_{iy} = f_{iy} + G_{iy} - \sum_{h=1}^{200}\sum_{j=1}^{2}\sum_{t=1}^{12} a_{ijt}X_{hjt} \tag{7}$$

Where: f_{iy} = Initial fish stock.

Finally, a sustainable fish use rate is set (Downing & Plante, 1993). Equation 8 describes the sustainable resource use.

$$S_{iy} = s_i * G_{iy} \tag{8}$$

Where: S_{iy} = Sustainable fish resource use in year y.

s_i = Sustainable fish use rate.

5. Impacts of nature-based tourism at the community level
5.1 Unmanaged natural resources

In our first scenario where natural resources are unconstrained and can be unsustainably extracted or harvested we quantify the attractiveness and costs of an unconstrained fish sector. The solution of a mathematical programming model determines the opportunity cost (shadow prices) of scarce resources (Brooke et al., 1992). The results at the community level show that the highest opportunity costs are for fishing in the rainy season (NAD$15 per day) and flood season (NAD$33 per day). This means that within these time periods fishing is the most financially beneficial activity and households with additional labour capacity would rationally allocate their time to fishing. The unconstrained natural resources scenario shows that in the flood season households shift their labour away from tourism employment to fishing. This shift occurs for two reasons (i) as the catch per unit effort for fishing increases in the flood season, increasing labour productivity for households, and (ii) demand for labour from tourism decreases as flood season coincides with the off-peak tourism season. This situation highlights the potential instability of tourism income conflicting with the conservation needs that tourism depends on. Whereas fishing in the rainy and flood season is efficient due to high catch per unit effort, for forest resources harvesting in the dry season returns the highest opportunity cost (NAD$20 per day) according to the model.

Results show that in all seasons households benefit from allocating time to the exploitation of natural resources for their subsistence consumption and for cash income generation. However, the model's unconstrained natural resource scenario reveals the opportunity costs of nature conservation. The opportunity costs can provide important information for developing sustainable regional management plans and may also partially explain why households still extract unsustainable levels of natural resources in CBNRM and conservancies (Abbott & Campbell, 2009; Koekemoer, 2003; Naesje et al., 2002; Turpie et al., 2005; Tweddle et al., 2015).

Fishing is of high regional importance for the community's livelihoods, but continuous overfishing decreases fish stocks. The unconstrained natural resource model quantifies a total community catch of 103 500 kg per year, which indicates significant overexploitation and negatively impacts the chance to develop a sustainable angling tourism industry.

Our model finds that fish resource extraction is highly sensitive to households' labour-leisure allocation. A sensitivity analysis for labour showed, if households would increase their overall labour time (decrease leisure), the community's catch can increase by over 200%, leading to serious consequences for the resource. Additionally, this would heavily influence the regional angling tourism, which is based on a high amount of fish and species richness. A further sensitivity analysis simulated an absence of the regional tourism sector. This would have a negative feedback effect, in that households would need to compensate for their lost income from nature-based tourism by reallocating their labour resources to subsistence fishing, thus further worsening the problem of overfishing.

In summary, although nature-based tourism, namely recreational fishing, is currently present in the Sikunga Conservancy, the community orients towards consumptive-uses of fish, threatening their livelihoods and the nature-based tourism sector. Interventions must balance the issues of employment creation, sustainable resource management and food security.

5.2 Sustainably managed natural resources (CBNRM scenario)

Nature-based tourism is implemented into the CBNRM concept to derive an economic benefit for rural communities from their sustainably managed natural resources. Thus, the CBNRM scenario explores the economic value of a sustainable fish resource use by the Sikunga Conservancy. According to the unconstrained scenario, the community catches

around 103 500 kg of fish per year, which can be interpreted as conservancy's contribution to the regional problem of overfishing. In order to conserve fish resources, the community has to reduce their fishing activity by around 65%. At community level, this results in a catch of 39 000 kg per year; this is stated as a sustainable fish use for Sikunga. The effects of angling tourism on fish resources are found to be just marginal, due to fishing lodges 'catch and release' resource treatment. The rate of fish used for consumptive use by fishing lodges and/or not survive 'catch and release', is only 1% of the unmanaged natural resource extraction and just 4% from the sustainably managed natural resource use.

Of particular significance in terms of planning and resource management is that the CBNRM scenario reveals a more profitable marginal value of fish resources in nature-based tourism compared to subsistence fishing. Table 2 shows a comparison of the fish extraction by the community and the angling tourism in Sikunga, as well as resource shadow prices: Fishing lodges use fish resource economically more beneficial compared to traditional fishing. A kilogram of fish used for recreational fishing has a value of NAD$715/kg, whereas the fish used for subsistence fishing has a value of only NAD$10/kg; possibly indicating a value of compensation and an economic incentive to conserve fish resources.

	Total use (kg)	Shadow price (NAD$/kg)
Households	39 000	10
Fishing lodges	1 615	715

Table 2: **Total fish extraction and shadow price in CBNRM scenario.**
Source: Author.

The result in constraining the consumptive use of fish to sustainable levels results in a change of labour allocation within the conservancy, increasing community's agricultural diversification. Around 30% of households' maize production shifts to protein rich cowpea to compensate the reduction of fish catch. This shift is largely driven by the need to meet subsistence protein levels consumption[3]. This highlights the importance of a shift to more nutritious crop, such as cowpea, should the conservancy prioritise the conservation and protection of fish stocks, otherwise nutrition can deteriorate.

---

[3] Growing cowpea is currently just marginal in Sikunga Conservancy.

Households also tend to focus more on their farm resources by allocating more household labour to on-farm activities and decreasing the use of hired-labour from outside Sikunga for cattle herding and milk production. Additionally, due to the decreased fishing activity, excess family labour has potentially negative consequence, in that fishing households then invest their surplus labour in harvesting forestry resources. This highlights the need for a holistic approach to natural resource management as if forestry practices are not monitored, this could lead to higher levels of deforestation, possibly affecting regions attractiveness for nature-based tourism. This issue needs to be seriously considered by the conservancy management.

Complementary to tourism-based development strategies within CBNRM, the CBNRM scenario reveals that Sikunga households shift their focus from fishing to nature-based tourism employments when natural resources are more protected. Thus, past labour leakages faced by Sikunga's fishing lodges, mainly in the flood season, can be better balanced; providing more stable income for households. During this time the Zambezi Region is an extensive floodplain system, offering great potential for recreational fishing along the Zambezi and Chobe Rivers. The reallocation of employment towards nature-based tourism highlights the potential of the sector to support households who are required to reduce their fishing activity due to the sustainable fish resource use. This also opens up the possibility for the nature-based tourism sector to contribute to compensation or alternative livelihood strategy development for those households who are unable to directly benefit from tourism employment opportunities.

Our model supports the commonly held view that just a comparable small number of the community benefits from tourism. In Sikunga, only 6% of the community directly benefits from employment in tourism activities. However, nature-based tourism contributes around one fifth to the community's social welfare. Therefore it might be attractive for the conservancy to promote the number of tourists and tourism enterprises, as to increase households that benefit from tourism. Although the benefits from tourism are currently limited and a remarkable decrease in community's fishing activity is required to help sustain the nature-based tourism sector, our model finds that as long as appropriate dietary substitutes for fish are available in the community, overall health and welfare is maintained despite the restriction on fishing.

Even a slight decrease in social welfare due to overfishing could be harmonised due to rural increased income and development opportunities by nature-based tourism; which when linked with benefit distribution mechanisms, which are mandated in conservancies, households could still gain. For example, we found that NAD$ 11 per adult per day fulfils all nutritional requirements of important macro- and micronutrients. Given the difference in values for fish for nature-based tourism vs subsistence consumption, such compensation and benefit distributions within the conservancy appear financially feasible, yet would require further research.

6. Conclusion

A mathematical programming model was constructed to analyse the impact of nature-based tourism on rural development and natural resource conservation in the Sikunga Conservancy, located in the North-east of Namibia. For improving the livelihoods of rural communities, using natural resources sustainably and deriving an economic benefit from nature-based tourism a suitable legal framework is given by the CBNRM concept.

An unmanaged natural resource scenario showed that households benefit from natural resources exploitation, especially fish, for their subsistence consumption and for cash income generation. Although nature-based tourism is currently present in Sikunga, the community is directed towards consumptive uses of fish, simultaneously threatening their livelihoods and the angling tourism sector. An absence of the regional nature-based tourism sector would lead to an increase in households' subsistence fishing, further worsening the problem of overfishing. However, our model revealed the opportunity cost of nature conservation, which can provide important information for developing sustainable regional management plans.

A sustainably managed natural resource (CBNRM) scenario was run to simulate a well-managed community following the sustainability principles of the CBNRM concept. Our model showed that, in terms of planning and resource management, nature-based tourism, namely recreational fishing lodges, use fish resources economically more beneficial compared to subsistence fishing; possibly indicating a value of compensation and an economic incentive to conserve fish resources. Currently just a small number of the Sikunga community directly benefits from tourism, but it highly contributes to community's social welfare; indicating the attractiveness for the conservancy to promote the number of tourists

and tourism enterprises. For a sustainable fish resource use and nature-based tourism, development restrictions on fish extraction are needed.

Sustainable fish resources form the basis for further tourism development, contributing to an increase in community members involved in tourism employment. In a well-managed CBNRM, fish resources should be used sustainably while stimulating the nature-based tourism development. Therefore, action from a Conservancy Management is needed, such as collectively introduced fish ban periods for subsistence fishing and support in community's crop diversification (training, seeds, etc.).

Overall our model has highlighted the challenges and trade-offs in developing nature-based tourism in areas where traditional livelihoods are highly dependent on consumptive uses of natural resources. Researchers and practitioners alike should use the opportunity costs of households that lose access to natural resources, in order to sustain the nature-based tourism sector, as well as offering alternative non-tourism based livelihood activities that substitute lost natural resource based income. Further research is needed for a long-term impact analysis of tourism: Dynamics and risks, such as varying tourism numbers, could be adapted within a model. Thus, future tourism developments could be explored and run for different scenarios in the Zambezi Region.

Disclosure statement
No potential conflict of interest was reported by the authors.

References
Abbott, JG & Campbell, LM, 2009. Environmental Histories and Emerging Fisheries Management of the Upper Zambezi River Floodplains. Conservation and Society, 7(2), 83-99.

Arjunan, M, Holmes C, Puyravaud JP & Davidar P, 2006. Do development initiatives
    influence local attitudes towards conservation? A case study from the Kalakad-
    Mundanthurai tiger reserve, India. Journal of Environmental Management, 79(2),
    188–97.

Babatunde, R & Qaim, M, 2010. Impact of off-farm income on food security and
    nutrition in Nigeria. Food Policy 35, 303-11.

Bandyopadhyay, S, Humavindu, M, Shyamsundar, P & Wang, L, 2009. Benefits to
    local communities from community conservancies in Namibia: An assessment.
    Development Southern Africa, 26(5), 733–54.

Bandyopadhyay, S & Tembo G, 2010. Household consumption and natural resource
    management around national parks in Zambia. Journal of Natural Resources Policy
    Research 2(1), 39–55.

Barnes, JI, MacGregor, JJ, Nhuleipo, O & Muteyauli, PI, 2010. The value of Namibia's
    forest resources: Preliminary economic asset and flow accounts. Development
    Southern Africa, 27(2), 159–76.

Britz, W, Ferris, M & Kuhn, A, 2013. Modeling water allocating institutions based on
    Multiple Optimization Problems with Equilibrium Constraints. Environmental
    Modelling & Software, 46, 196-207.

Brooke, A, Kendrick, D & Meeraus, A, 1992. Release 2.25, GAMS, A User's
    Guide. The Scientific Press, South San Francisco.

Brooks, J, Franzen, MA, Holmes, CM, Grote, MN & Mulder, MB, 2006. Testing
    Hypotheses for the success of different conservation strategies. Conservation Biology,
    20(5), 1528–38.

Clark, CW, 2006. The worldwide crisis in fisheries: Economic models and human
    Behaviour. Cambridge University Press, New York.

Conrad, JM, Gomes, CP, van Hoeve, W-J, Sabharwal, A & Suter, JF, 2012.
    Wildlife corridors as a connected subgraph problem. Journal of Environmental
    Economics and Management, 63, 1-18.

Downing, JA & Plante, C, 1993. Production of Fish Populations in Lakes. Can. J.
    Fish. Aquat. Sci., 50, 110-20.

FAO (Food and Agriculture Organization of the United Nations) (2015). The State of Food
    Insecurity in the World. Rome.

Fennell, D, 2008. Ecotourism and the myth of indigenous stewardship. Journal of

SustainableTourism 16 (2), 129–49.

Fiorella, KJ, Hickey, MD, Salmen, CR, Nagata, JM, Mattah, B, Magerenge, R, Cohen, CR, Bukusi, EA, Brashares, JS & Fernald, LH, 2014. Fishing for food? Analyzing links between fishing livelihoods and food security around Lake Victoria, Kenya. Food Security, 6(6), 851-60.

Fisher, B & Treg, C, 2007. Poverty and biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. Ecological Economics 62(1), 93–101.

Fabricius, C & Collins, S, 2007. Community-based natural resource management: governing the commons. Water Policy, 9(2), 83-98.

Haggblade S, Hazell PBR & Reardon TA, 2007. Transforming the rural nonfarm economy: Opportunities and threats in the developing world, Johns Hopkins University Press, Baltimore.

Hazell, PBR & Norton, RD, 1986. Mathematical Programming for Economic Analysis in Agriculture. Macmillan Publishing Company, New York.

Gladwin, CH, Thomson, AM, Peterson, JS & Anderson, AS, 2001. Addressing food security in Africa via multiple livelihood strategies of women farmers. Food Policy, 26, 177-207.

Guzman, LEP, Zamora, OB & Bernardo, DFH, 2015. Diversified and Integrated Farming Systems (DIFS): Philippine Experiences for Improved Livelihood and Nutrition. Journal of Developments in Sustainable Agriculture, 10(1), 19-33.

Herforth, A, Frongillo, EA, Sassi, F, Mclean, MS, Arabi, M, Tirado, C, Remans, R, Mantilla, G, Thomson, M & Pingali, P, 2014. Towards an integrated approach to nutritional quality, environmental sustainability, and economic viability: research and measurement gaps. Ann. N. Y. Acad. Sci., 1332, 1-21.

Kaiser, HM & Messer, KD, 2011. Mathematical Programming for Agricultural, Environmental, and Resource Economics. John Wiley & Sons, Inc., Hoboken, NJ.

Kamwi, JM, Chirwa, PWC, Manda, SOM, Graz, PF & Kätsch, C, 2015. Livelihoods, land use and land cover change in the Zambezi Region, Namibia. Population and Environment, 37(2), 207-30.

Kanapaux, W & Child, B, 2011. Livelihood activities in a Namibian wildlife conservancy: A case study of variation within a CBNRM programme. Oryx, 45(3), 365–72.

Koekemoer, JH, 2003. A fish ecological study of rivers and floodplains in the eastern

Caprivi, Namibia. Academic Dissertation, Faculty of Natural Science, Rand Afrikaans University.

Lapeyre, R, 2011. The Grootberg lodge partnership in Namibia: towards poverty alleviation and empowerment for long-term sustainability. Current Issues in Tourism, 14(3), 221-34.

Lepper, CM & Schroenn, J, 2010. Community-based natural resource management, poverty alleviation and livelihood diversification: a case study from northern Botswana. Development Southern Africa 27 (5), 725–39.

Lindsey, P, Alexander, RR, du Toit, JT & Mills, MGL, 2005. The potential contribution of ecotourism to African wild dog Lycaon pictus conservation in South Africa. Biological Conservation, 123(3), 339–48.

Lipton, M, 1968. The theory of the optimising peasant. Journal of Development Studies, 4(3), 327-51.

Liu, W, Vogt, CA, Luo, J, Guangming, H, Frank KA & Liu, J, 2012 Drivers and Socioeconomic Impacts of Tourism Participation in Protected Areas. PLoS ONE 7(4): e35420.

Maruod, ME, Breima, EE, Elkhidir EE & El Naim, AM, 2013. Impact of Improved Seeds on Small Farmers Productivity, Income and Livelihood in Umruwaba Locality of North Kordofan, Sudan. International Journal of Agriculture and Forestry, 3(6), 203-8.

Mbaiwa, JE & Stronza, AL, 2010. The effects of tourism development on rural livelihoods inthe Okavango Delta, Botswana. Journal of Sustainable Tourism, 18(5), 635–56.

Mendelsohn, J, Obeid, S, de Klerk, N & Vigne, P, 2006. Farming systems in Namibia. RAISON (Research & Information Services of Namibia), ABC Press, South Africa.

Mukwada, G & Manatsa, D, 2012. Assessment of Community-based Natural Resource Management in the Savannas Using the Capacity Continuum - Multiple Drivers Model. Journal of Human Ecology, 40(1), 69-84.

Naesje, TF, Strand, R, Hay, C, Purvis, J, Thorstad, EB, Abbott, J & Nickanor, N, 2002. Shared resource management on the Zambezi/Chobe systems in northeast Namibia: Current practices and future opportunities river survey February-August 2002. NINA (Norwegian Institute for Nature Research) Project Report 18, 1-72, Trondheim.

NASCO (Namibian Association of CBNRM Support Organisations) 2009. Conservancy profile, Sikunga Conservancy. http://www.nacso.org.na/SOC_profiles/conservancyprofile.php?ConsNum=56. Accessed 13 October 2014.

Nash, S, 2009. Ecotourism and other invasions. Bioscience, 59(2), 106–10.

NNF (Namibia Nature Foundation) 2013. GDI Area Proposal - CBNRM and Wetland Conservation, Sikunga Conservancy, Caprivi region, Namibia. Windhoek.

NSA (National Statistics Agency) 2012. Namibia Household Income & Expenditure Survey (NHIES) 2009/2010. Windhoek.

Orsi, F, Church, RL & Geneletti, D, 2011. Restoring forest landscapes for biodiversity conservation and rural livelihoods: A spatial optimization model. Environmental Modelling and Software, 26, 1622-38.

Owusu, V, Abdulai, A & Abdul-Rahman, S, 2011. Non-farm work and food security among farm households in Northern Ghana. Food Policy, 36, 108-18.

Parviainen, T, 2012. Role of Community Forestry in Rural Livelihood and Poverty Alleviation in Ohangwena and Caprivi Regions in Namibia. Academic Dissertation, Department of Economics and Management, Publication Nr. 55, Helsinki.

Silva, JA & Mosimane, AW, 2012. Conservation-Based Rural Development in Namibia: A Mixed-Methods Assessment of Economic Benefits. The Journal of Environment & Development, 22(1), 25-50.

Sims, KRE, 2010. Conservation and development: evidence from Thai protected areas. Journal of Environmental Economics and Management, 60(2), 94–114.

Stronza, A & Gordillo, J, 2008. Community views of ecotourism: Redefining benefits. Annals of Tourism Research, Vol. 35, 444-68.

Stronza, A, 2010. Commons management and ecotourism: ethnographic evidence from the Amazonas. International Journal of the Commons, 4(1), 56-77.

Suich, H, 2010. The livelihood impacts of the Namibian community based natural resource management programme: a meta-synthesis. Environmental Conservation, 37(1), 45–53.

Sweeney, L, Baker, A, Thaniseb, A, Brown, C, Tweddle, D, Hay, C & van der Waal, B, 2010. A Preliminary Economic Assessment of the Contribution of Fishing Lodges in the Caprivi Region to the Local Economy. Windhoek.

Tao, TCH & Wall, G, 2008. Tourism as a sustainable livelihood strategy. Tourism

Management, 30(1), 90-8.

Tesso, G, Emana, B & Ketema, M, 2013. Maintaining minimum livelihood under changing climate in North Shewa Zone, Ethiopia: a mathematical programming approach. International Research Journal of Agricultural Science and Soil Science, 3(2), 51-65.

Turpie, J, Lange, G-M, Martin, R, Davies, R & Barnes, JI, 2005. Namibia's protected areas: Their economic worth and the feasibility of their financing. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek.

Turpie, J, Barnes, JI, Lange, G-M & Martin, R, 2010. The economic value of Namibia's protected area system and case for increased investment. Report to Strengthening the Protected Area Network (SPAN) Project.

Tweddle, D & Hay, CJ, 2012. Final Technical Report December 2012. Technical Report no. MFMR/NNF/WWF/PhaseII/8.

Tweddle, D, Cowx, IG, Peel, RA & Weyl, OLF, 2015. Challenges in fisheries management in the Zambezi, one of the great rivers of Africa. Fisheries Management and Ecology, 22, 99-111.

USAID (United States Agency for International Development) 2013. CBNRM Workshop: Cutting Across Multi-Sector Divides, January 16 & 17, 2013, Workshop Proceedings. Washington DC.

Vanderpost, C, 2006. Pathways of human sprawl in wilderness buffer zones. Population and Environment, 27, 285-306.

Vernooy, R, Nelles, W, Campilan, D & Li, Z, 2009. Learning to evaluate capacity development and collaborative learning about community-based natural resource management: lessons from Asia. Working Paper 2009-4, International Potato Center (CIP), Lima.

Waylen, KA, McGowan PJK, Pawi Study Group & Milner-Gulland EJ, 2009. Ecotourism positively affects awareness and attitudes but not conservation behaviours: a case study at Grande Riviere, Trinidad. Oryx, 43(3), 343–51.

WB (World Bank) 2015. Price level ratio of PPP conversion factor (GDP) to market exchange rate. http://data.worldbank.org/indicator/PA.NUS.PPPC.RF. Accessed 16 June 2015.

West, P, 2008. Tourism as science and science as tourism: environment, society, self, and other in Papua New Guinea. Current Anthropology 49(4), 597–626.

Winter, EM, Fasse, A & Frohberg, K, 2015. Food Security, Energy Equity, and the Global Commons: a Computable Village Model applied to sub-Saharan Africa. Regional Environmental Change, 15, 1215-27.

WFP (World Food Programme) 2015. Assessing Nutritional Requirements. http://www.wfp.org/fais/nutritional-reporting/assessing-nutritional-requirements. Accessed 25 January 2015.

WTTC (World Travel & Tourism Council) 2014. Travel & Tourism - Economic Impact 2014: Namibia. London.

Zeppel, H, 2006. Indigenous ecotourism: sustainable development and management. Ecotourism Book Series (Book 3), CAB International, Wallingford.