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Zusammenfassung

Natürliche Ressourcen bilden die Lebensgrundlage vieler ländlicher Haushalte in Entwicklungsländern. Die Auswirkungen unklarer Eigentumsrechte, extremer Armut, nicht funktionierender Märkte und Institutionen trägt dazu bei, dass natürliche Ressourcen, mit samt den Gemeinschaften, die von ihnen abhängen, dem Risiko der Gemeingüter-Tragik ausgesetzt sind.

Gemeinschaftliches Management natürlicher Ressourcen (CBNRM) ist ein Ansatz, der es Gemeinschaften ermöglicht, ihre natürlichen Ressourcen nachhaltig zu nutzen, und damit ökonomische Entwicklung und soziale Gleichheit verbessert. CBNRM erfreut sich immer größerer Beliebtheit in Afrika südlich der Sahara, und sowohl Regierungs- als auch Nichtregierungsorganisationen fördern die Vorteile des Programms. Die wenigen empirischen Studien, die sich mit den ökonomischen und ökologischen Auswirkungen CBNRMs beschäftigen, kommen allerdings zu unterschiedlichen Ergebnissen hinsichtlich positiver oder negativer Programmauswirkungen.

Diese Arbeit verfolgt daher einen ganzheitlichen Ansatz. Mit Hilfe einer detaillierten Fallstudie in einem CBNRM Gebiet (das Sikunga Naturschutzgebiet) in der nordöstlichen Sambesi Region Namibias werden drei spezifische Forschungsziele verfolgt. Es geht konkret darum, (1) unterschiedliche Existenzstrategien innerhalb der Gemeinschaft zu identifizieren, die jeweiligen Unterschiede in der Ressourcennutzung zu erkennen, und zu analysieren, wie diese Unterschiede die ökonomische Gleichheit in der Gemeinschaft bedingen, (2) die ökonomischen Verbindungen zwischen den verschiedenen ökologischen und nicht-ökologischen Aktivitäten innerhalb der CBNRM-Wirtschaft zu untersuchen; und (3) zu analysieren, wie individuelle und ökologische Faktoren Kooperation zum Schutz der natürlichen Ressourcen schwächen.

Die ersten beiden Zielstellungen wurden anhand einer Befragung von 200 Haushalten aus dem Sikunga Naturschutzgebiet untersucht, die im September und Oktober 2012 durchgeführt wurde. Der Datensatz umfasst detaillierte Informationen über Einkommensquellen, Zeitallokation, Konsum und Ausgaben, Nutzung natürlicher Ressourcen, Viehwirtschaft und Pflanzenproduktion. Außerdem wurden Informationen zu sozio-demographischen Haushaltseigenschaften und Sozialkapital gesammelt.

Für die Analyse des Datensatzes wurden zwei aufeinander aufbauende empirische Strategien genutzt. Entsprechend der ersten Zielstellung, wurde eine zweistufige Clusteranalyse durchgeführt, die die Haushalte anhand ihrer jeweiligen Existenzstrategie in unikale Gruppen (Cluster) kategorisiert. Diese

Haushaltscluster wurden dann benutzt, um eine ökologisch-erweiterte Social Accounting Matrix (ESAM) zu entwickeln. Diese ESAM diente als Grundlage zur Durchführung unbeschränkter und beschränkter Multiplikatoranalysen, um, entsprechend der zweiten Zielstellung, die Verbindungen zwischen ökologischen und nicht-ökologischen Aktivitäten innerhalb der Gemeinschaft zu identifizieren.

Zur Bearbeitung der dritten Zielstellung wurde eine Serie von Lab-in-the-Field-Experimenten zur Eruierung des Kollektivgut-Verhaltens der Gemeinschaftsmitglieder im Sikunga Naturschutzgebiet im September und Oktober 2014 durchgeführt, wobei die Haushalte nur teilweise mit denen aus der vorangegangen Welle übereinstimmen. Die experimentellen Daten sind in Paneldatenform und erlauben daher die Anwendung von Generalized Least Squares Random Effects und Poisson Random Effects Modellen.

Methodisch trägt diese Arbeit zum gegenwärtigen Forschungsstand in der Verhaltensökonomie in der Literatur zu öffentlichen Gütern auf verschiedene Weise bei. Erstens beinhaltet das Kollektivgut-Experiment tatsächliche Anstrengungen seitens der Teilnehmer, welche sowohl im Feld als auch im Labor durchgeführt werden können. Während tatsächliche Anstrengungen im Labor im Laufe der Zeit zum Standard geworden sind, steht die Umsetzung im Feld vor allerlei Herausforderungen. Zum Beispiel hängen diese Aufgaben von Fähigkeiten zu rechnen und zu lesen, oder von einfachen physischen Eigenschaften wie der Sehstärke, ab. Besonders in ländlichen Gebieten Afrikas südlich der Sahara sind diese Fähigkeiten unter dem Niveau der westlichen Welt. In dieser Arbeit wird eine tatsächliche Anstrengung so modelliert, dass diese Fallstricke überwunden werden können.

Zweitens, ist dies die erste empirische Studie, die konsistent die Auswirkungen von Risiko in einem Kollektivgutexperiment untersucht, indem Risiko simultan auf das private und das öffentliche Gut angewandt wird. Durch den Vergleich des Teilnehmerverhaltens in einem risiko-neutralen und in einem risiko-behafteten Kontext in zwei aufeinanderfolgenden Experimenten, ist es möglich, den Effekt von Risikoaversion und Wahrscheinlichkeitsgewichtung zu kontrollieren und letztlich den Einfluss von Risiko auf Kooperationsverhalten zu identifizieren. Auf diese Weise trägt diese Arbeit eine neue Dimension zum, von Ostrom entwickelten, Teufelskreis der Kooperation bei.

Drittens ermöglicht das Experiment die Quantifizierung des Risikoeffekts auf das Anstrengungslevel in einer kontrollierten Umgebung. Während viele Studien quasi-experimentelle Methoden anwendeten, erfolgt in dieser Arbeit die Quantifizierung des Risikoeffekts zum ersten Mal in einer kontrollierten Umgebung.

Die Ergebnisse dieser Arbeit liefern neue Erkenntnisse in der Verhaltensökonomie zu Kollektivgütern und können zu einer Verbesserung der Programmgestaltung von CBNRMs beitragen. Erstens ist die Wirtschaftsstruktur in der Studienregion zugunsten der wohlhabenderen Haushalte ausgerichtet und zu denen, die näher an den Hauptinfrastrukturen leben, wie Straßen und Elektrizität. Mit Hilfe des Programms konnten Eigentumsrechte auf die Gemeinschaft übertragen werden, aber ohne Entwicklungsstrategien, die speziell die verletzlichen Haushalte in der Gemeinschaft unterstützen, konnte die Elite durch kommerziellen Abbau und Handel größere Renditen aus den natürlichen Ressourcen ziehen. Ärmere Haushalte sind dagegen weiterhin auf die natürlichen Ressourcen zur Deckung ihres Eigenbedarfs angewiesen.

Zweitens, unter Berücksichtigung der biologischen Grenzen des Naturschutzgebietes, gibt es nur wenig ökonomische Integration zwischen den ökologischen und nicht-ökologischen Aktivitäten innerhalb der Dorfgemeinschaft. Im Gegensatz dazu, gibt es starke Verbindungen zwischen verschiedenen ökonomischen Aktivitäten mit erhöhter Nachfrage für eine bestimmte Ressource. Dies führt zu erhöhter Nachfrage für die meisten anderen Rohstoffe, anstatt zur Stimulation anderer Sektoren außerhalb des Rohstoffabbaus in der Dorfgemeinschaft. Daher dürfte es für die Gemeinschaft schwer sein, ihr Einkommen aus dem CBNRM-Programm zur Diversifizierung ihrer wirtschaftlichen Aktivitäten zu nutzen und langfristig aus der Ressourcennutzung herauszukommen.

Drittens identifiziert diese Arbeit potentielle verhaltensökonomische Faktoren, die die positiven Auswirkungen des CBNRMs beschränken könnten. Die Ergebnisse des Lab-in-the-Field-Experiments zeigen, dass Risiko Aufwands- und Kooperationsbereitschaft negativ beeinflusst. In einem risiko-neutralen Kontext waren Haushalte eher bereit, in öffentliche Güter zu investieren als in einem risiko-behafteten Kontext. Weiterhin wurde belegt, dass gemeinsame Strategien zur Verbesserung der Kooperation und Kommunikation in Gegenwart von Risiko nicht effektiv sind. Dies hebt eine potentielle Schwachstelle des CBNRM Programmdesigns hervor, wobei die Risiken des gemeinschaftlichen Vermögens und Unternehmen weder abgemildert noch versichert sind. Diese nicht versicherten Risiken könnten für Haushalte Anreiz sein, sich von der Gemeinschaft abzusetzen und in ihr eigenes Unternehmen zu investieren, zum Beispiel in die Umwandlung von gemeinschaftseigenen Lebensraum für Wildtiere in privates landwirtschaftliches Eigentum.

Insgesamt zeigen die Ergebnisse dieser Fallstudie, dass das CBNRM Programm wahrscheinlich nur begrenzt Vorteile für die Forschungsregion haben wird. In Hinsicht auf die Literatur deuten die Ergebnisse an, warum die ökonomischen Effekte von CBNRM bisher nicht eindeutig sind. Es wird empfohlen, verschiedene Methoden und empirische Strategien, die sowohl individuelle Haushalte als auch ihre Überlebensstrategien ins Zentrum stellen, in der Analyse zu berücksichtigen. Letztlich suggerieren die Ergebnisse des Experiments, dass die Gegenwart ungemilderter Risiken eine Bedrohung für Gemeinschaftsprojekte, die auf Kooperation bauen, darstellt. Akteure aus der Entwicklungspraxis könnten daher in Betracht ziehen, wie Gemeinschaften gegenüber Risiken, wie Niederschlagsveränderungen oder Konflikte zwischen Wildtieren und Menschen, versichert werden können.

Schlagworte: Natürliche Ressourcen, Gleichheit, Ökonomische Entwicklung

Abstract

In remote areas of developing countries, the livelihoods of many rural households are highly dependent on natural resources. However, the impact of poorly defined property rights, extreme levels of poverty, dysfunctional markets and government institutions place the natural resources, and the communities that depend on them, at risk of becoming another tale of the "tragedy of the commons".

Community based natural resource management (CBNRM) was promoted as an approach that would enable communities to sustainably manage their natural resources which would also enhance economic development and economic and social equality. CBRNM has become increasingly popular in sub-Saharan Africa, and governments and NGOs alike continue to promote the perceived benefits of CBNRM programmes. The few extant empirical studies, however, that investigate economic and environmental impacts of CBNRM derive inconsistent conclusions whether CBNRM impacts are positive or negative.

The aim of this thesis is to evaluate the role of social, natural, physical, human and financial capital in influencing the impact of CBNRMs. This thesis therefore takes a holistic approach by means of a detailed case study on a single CBNRM area (the Sikunga Conservancy) in the north-eastern Zambezi region of Namibia, this thesis focuses on three specific research objectives: (1) to identify the different livelihood strategies within the community, to investigate the extent to which different strategies utilize natural resources, and to analyse how this improves economic equality within the community; (2) to examine the economic linkages between the different environmental and non-environmental activities within the CBNRM-economy; and (3) to investigate how individual and environmental factors may degrade cooperation to protect natural resources.

The first two objectives are met using household survey data from 200 households in the Sikunga Conservancy collected in September and October 2012. The data set contains detailed information on income sources, time-use, consumption and expenditure data, harvesting of natural resources, livestock and crop management. Information on each household's socio-demographics and social capital was also collected.

The survey data is utilized in two different empirical strategies that build upon each other. To meet the first research objective, a two-step cluster analysis is conducted, identifying the unique groups of households within the study area which adopt similar livelihood strategies. The household clusters were

then used to develop an environmentally extended village social accounting matrix (ESAM). According to the second objective, the ESAM serves as a basis to conduct a series of unconstrained and constrained multiplier analyses to identify the linkages between environmental and non-environment based activities, and the different household groups and other institutions within the community. The third objective is addressed via a series of artefactual lab-in-the-field experiments to elicit community members' behaviour towards public goods that were conducted in the same community, with a partial overlap between households, in September and October 2014. The lab-in-the-field experiment data follows the form of panel data. As such, a series of Generalized Least Squares Random Effects and Poisson Random Effects models are applied.

Methodologically, the thesis makes several contributions to the current research of behavioural economics in public good literature. First, it provides a real-effort based public good game which can be implemented in the field as well as in laboratories. Whilst laboratory real-effort tasks are common place and have been relatively standardized over time, the conduct in the field has several challenges. For example, these tasks are heavily biased towards basic levels of numeracy, literacy or even simple physical characteristics such as level of sight. Especially in rural areas of sub-Saharan Africa where numeracy and literacy levels may be well below the western world, and simple things such as sight or hearing deprivation remain untreated. This thesis details a real-effort task which overcomes these constraints by utilising a simple physical sorting task.

Second, it is the first empirical study of its kind to consistently examine the impact of risk in a public good game; by simultaneously applying risk to the private and public goods. By comparing participants' behaviours in a risk neutral and risky setting in two sequential public good games the experiment is able to limit the impact of risk aversion and probability weighting and finally, identify the impacts of risk on cooperative behaviour. In this way, it adds a new dimension to the virtuous circle of cooperation developed by Ostrom.

Furthermore, by utilising a real-effort based experiment, it also quantifies the impact of risk on exertion levels in a controlled environment. Whilst many studies have used quasi-experimental methods and econometrics to quantify the impact of risk on effort levels, this is the first time that it has been quantified in a controlled environment.

Empirically, the results obtained in this thesis contribute to existing knowledge and help improve CBNRM programme designs. Firstly, in the study area, the structure of the economy is heavily biased towards the wealthier households, and those located near the main infrastructure such as roads and electricity. CBNRM has transferred property rights for natural resources to the community, but without development policies that specifically target vulnerable households within the community the elite and wealthy households have been able to extract greater rents from the natural resources via more commercial harvesting and trading. Poorer households largely continue to rely on natural resources for subsistence.

Secondly, when the biological limits of the conservancy are taken into consideration, there is little economic integration between the environmental and non-environmental activities within the village economy. Conversely, there are strong interlinkages within different environmental activities, with increased demand for natural resources, leading to increased demand for most other environmental resources, rather than stimulating other off-farm sectors within the village economy. Therefore, communities may struggle to use income derived from CBNRM to diversify their economy and shift away from natural resource consumption.

Thirdly, as well as highlighting the importance of the local underlying economic structures when designing CBNRM programmes, this study also identifies potential behavioural factors which may limit the positive impact of CBNRM. The results of the lab-in-the-field experiment show that risk negatively impacts on effort and cooperation levels. Faced with pay-off equivalent situations, households were more likely to invest in public goods in risk neutral contexts than in risky contexts. Furthermore, common strategies to enhance cooperation such as communication and observation proved to be ineffective in the presence of risk. This highlights a potential flaw in the design of many CBNRM programmes where the risk to community owned assets and enterprises are unmitigated and uninsured. The uninsured risks in community assets may create the incentive for households to reduce their contributions to public goods and invest in their own private assets and enterprises, to the detriment of community-owned ones such as the conversion of community-owned wildlife grazing lands to private land for agriculture.

Overall the results of the case study show that the CBNRM programme in the study area is likely to have limited benefits. With respect to the literature they may help to explain why the literature to date on

the economic impacts of CBNRM has been inconclusive. It is recommended to consider multiple methods and empirical strategies that consider individual households and livelihood strategies at the centre of analysis. Finally, the experiment results suggest that the presence of unmitigated risk poses a threat to community projects that are dependent on cooperation. Development practitioners may need to consider ways of insuring community projects against risks such as weather and wild-life conflicts.

Keywords: Natural Resources, Equality, Economic Development

Table of Contents

Acknowledgements 1

Zusammenfassung 4

Abstract 8

Table of Contents 12

List of Tables 15

List of Figures 16

List of Abbreviations 17

1 Introduction 18

1.1 Motivation and Background 18

1.2 Objectives 19

1.3 Data and Study Area 22

1.4 Methods 24

1.5 Results 26

1.6 Outline 27

References 29

2 CBNRM and the Inequality of Environmental Income: Case Study from a Namibian Conservancy 37

2.1 Introduction 39

2.2 CBNRM in Namibia 40

2.3 Conceptual Framework and Key Definitions 41

2.3.1 Conceptual Framework 41

2.3.2 Key Definitions 43

2.4 Study Area and Data 44

2.4.1 Data 44

2.4.2 Study Area 44

2.5 Method 46

2.5.1 Cluster Analysis: Identifying Unique Livelihood Strategies 46

2.5.2 Multinomial Logit Model: Identifying Determinants of Environmental Income-based Livelihoods 47

2.6 Results 48

2.6.1 The Contribution of Environmental Income to Equality 48

2.6.2 Environmental Income and Equality Across Heterogeneous Livelihoods 49

2.6.3 Determinants of Environmental Income-based Livelihoods 54
2.7 Discussion 56
2.8 Summary and Conclusion 57
References 59
Appendix 66
3 Assessing Natural Resource Management Through Integrated Environmental and Social-economic Accounting: The Case of a Namibian Conservancy 67
3.1 Introduction 69
3.2 Study Area and Data 71
3.2.1 Study Area 71
3.2.2 Data 72
3.3 Method 73
3.4 The Environmentally Extended Sikunga Village SAM 73
3.4.1 Activities 74
3.4.2 Commodities 75
3.4.3 Factors 76
3.4.4 Institutions 76
3.4.5 Capital 78
3.4.6 Government and Conservancy 78
3.4.7 Rest of the Village, Rest of Namibia, Rest of World 78
3.5 Multiplier Analysis 79
3.6 Results 81
3.6.1 The Economic Contribution of Environment and Non-environment-based Activities to the Village Economy 81
3.6.2 Structural Linkages Between Environmental and Non-environment-based Activities 85
3.6.3 The distribution of environmental income across livelihoods and regions 86
3.7 Discussion 88
3.8 Conclusion 90
Notes 92
References 93
4 The Effect of Risk on Cooperation and Effort: A Lab-in-the-field Experiment 102
4.1 Introduction 104

4.2 Study Area ... 106
4.3 Experiment Design ... 106
4.3.1 Experiment Process ... 107
4.3.2 Real Effort vs. Chosen Effort in Public Goods Experiments ... 107
4.3.3 Real-Effort Task ... 108
4.3.4 Field Setting ... 109
4.3.5 Social dilemma - Without and With risk ... 110
4.4 Treatments ... 112
4.4.1 Baseline - Effort ... 112
4.4.2 Baseline – Risk ... 113
4.4.3 Communication ... 114
4.4.4 Observation ... 114
4.4.5 Communication and Observation ... 115
4.5 Econometric Method ... 115
4.6 Results ... 116
4.6.1 The Impact of Risk on Cooperation ... 118
4.6.2 The Impact of Risk and Shocks on Effort ... 119
4.6.3 The Impact of External Treatments on Cooperation and Effort With and Without Risk ... 121
4.6.4 The Impact of Individual Characteristics on Cooperation and Effort ... 123
4.7 Conclusion ... 123
References ... 125
Appendices ... 133
Appendix 1: Variables used in regressions ... 133
Appendix 2: Full regression tables ... 134
Appendix 3: Experiment Procedure ... 135
Experiment Instructions ... 137
Additional Instructions for Treatments – implemented after 5 rounds ... 145
5 Conclusion ... 146

List of Tables

Table 1: Overview of Essays 28
Table 2: Gini Coefficient for Different Income Sources 48
Table 3: Distribution of Variables Used for Cluster Analysis Across the Four Clusters 50
Table 4: Comparison of Income Sources Across Each Cluster 51
Table 5: Comparison of Human, Physical, Financial, and Natural Capital Across Each Cluster 53
Table 6: Multinomial Logit Regression 55
Table 7: Description of variables used in Cluster Analysis 66
Table 8: Overview of ESAM Framework 74
Table 9: Income sources for the Livelihood Strategies in Sikunga 77
Table 10 ESAM with Constrained and Unconstrained accounts 81
Table 11: Aggregate Village Extended Environmental Social Accounting Matrix of Sikunga 83
Table 12: Aggregate Village Extended Environmental Social Accounting Matrix of Sikunga (continued) . 84
Table 13: Constrained Multiplier Analysis – Livestock, Slash-and-burn, Fish and Timber Sectors Constrained 86
Table 14: Normalised Income Constrained Multipliers 88
Table 15: Parameters for the public good games… 112
Table 16: Summary of treatments 115
Table 17: Descriptive Results of Sample 117
Table 18: Econometric Results – impact of risk on cooperation 118
Table 19: Econometric Results – impact of risk on effort 120
Table 20: Econometric Results – influence of treatments on cooperation in the presence of risk 122
Table 21: List of variables used in the regressions 133
Table 22: Regressions without interaction terms 134

List of Figures

Figure 1: Map of Sikunga, its infrastructure and villages 23
Figure 2: Conceptual Framework 42
Figure 3: Lorenz Curves for Sikunga Households With and Without Environmental Income 49
Figure 4: The cyclical nature of cooperation 107
Figure 5: Marked tokens for the private and public good. 109
Figure 6: Field Setting 110
Figure 7: Value of Wheat Chips 139
Figure 8: Value of Tree Chips 140
Figure 9: Example of the playing sheet for game 1 142

List of Abbreviations

AIC	Akaike Information Criteria
BIC	Bayesian Information Criteria
CBFM	Community Based Fisheries Management
CBNRM	Community Based Natural Resource Management
EUDN	European Development Network
ESAM	Environmentally Extended Village Social Accounting Matrix
FONA	Forschung für Nachhaltige Entwicklung
FPA	Fish Protected Area
ISSRM	International Symposium on Society and Resource Management
NAD	Namibian DollarS
NRM	Natural Resource Management
SAM	Social Accounting Matrix
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SEEA	System of Environmental and Economic Accounting
SLF	Sustainable Livelihoods Framework

1 Introduction

1.1 Motivation and Background

Complex socio-economic and environmental interactions, depleting natural resources and a changing climate have created new pressures on the rural poor in developing countries (Schmitz et al., 2014; Verburg et al., 2015; Vliet et al., 2015). The continued destruction of the natural environment is likely to cause irreparable changes in the social and economic systems of the world's most vulnerable communities (Biermann et al., 2012; Cavendish, 2000; Dasgupta et al., 2005; Richardson et al., 2009), the majority of who reside in remote rural areas overlapping with the areas rich in biodiversity (Redford et al., 2008).

The reasons behind rapid environmental loss in areas rich in biodiversity are complex and context specific. Much blame has often been laid on the poor, who consume the resources because there are few other livelihood strategies available to them (Holden, 1997), but the story is far more complicated than this. The institutions, processes and economic structures that govern the use of natural resources in these areas often provide a perverse incentive regarding the use of natural resources (Barbier, 2010; Dasgupta et al., 2005; Lambin et al., 2001; Lufumpa, 2005).

Top-down "coercive conservation" governance approaches failed and were largely condemned as they were socially and economically destructive, as well as in many cases ecologically ineffective (Adams and Hutton, 2007; Adams, 2003; Brandon and Wells, 1992; Dressler et al., 2010). Acknowledgment of the failures of top-down approaches helped lead to the rise and popularity of community based natural resource management (CBNRM) (Agrawal and Gibson, 1999; Berkes, 2004; Leach et al., 1999).

CBNRM is a process of decentralisation where decisions regarding the use of, and the benefits derived from, natural resources are placed in the hands of local agents and institutions (Barrett et al., 2005; Blaikie, 2006; Nelson and Agrawal, 2008). CBNRM is however more than decentralisation; it is an approach to conservation coupled with principles of sustainable economic growth and social and financial equality (Berkes, 2004, 1989; Brown, 2002; Kellert et al., 2000; Western and Wright, 1994).

Despite its ideological appeal and popularity, particularly amongst governments in sub-Saharan Africa, the empirical results of CBNRM remain inconclusive. At the macro-level, the ecological results have tended to be positive, with increases in wildlife appearing correlated with CBNRM programmes across Botswana, Namibia and Tanzania (Roe et al., 2009). Increases in income in countries with CBNRM programmes have also been found (Arntzen et al., 2007; Boudreaux and Nelson, 2011; Frost and Bond, 2008), although not consistently (Suich, 2010). Most positive impacts on wealth within CBNRM are found with methods where the counterfactual is difficult to identify, and issues in endogeneity and self-selection are not easily addressed.

At the household level, the impact of CBNRM on income has been statistically insignificant (Pailler et al., 2015; Riehl et al., 2015; Suich, 2013), although improvements in food security (Pailler et al., 2015) and health (Naidoo and Johnson, 2013; Riehl et al., 2015) have been found.

One of the challenges in consistently identifying the impacts of CBNRM is that the impacts differ by livelihoods (Collomb et al., 2010; Kanapaux and Child, 2011; Sallu et al., 2009), and can be indirect and dynamic, depending upon the interactions between economic agents in the community (Balint and Mashinya, 2008, 2006).

In this thesis, the overall objective is to understand how the behaviour of households influences the flow of resources within the economy, and in turn, how these impact on social institutions and welfare of the community. This therefore leads to the three essays that form the body of this thesis:

Essay 1: CBNRM and the inequality of environmental income: Evidence from a Namibian conservancy

Essay 2: Evaluating the role of natural resources in a community based natural resource management economy: The case of a Namibian conservancy

Essay 3: The effect of idiosyncratic and covariate risk on the provision of public goods: a real effort experiment from Namibia

1.2 Objectives

Given the often conflicting and disparate results within the existing literature, this thesis aims to conduct a detailed case study of a single study area to provide a comprehensive understanding of how the flows of natural resources and direct and indirect benefits within a CBNRM economy contribute to sustained and equitable economic growth amongst the heterogeneous livelihoods. In focusing on a single study area, and by observing the within-case variation the results obtained from a case study can help contribute a theory which better explains why CBNRM delivers such inconsistent results at the macro level (Eisenhardt, 1989). The essays contained within this thesis therefore build on one another to achieve the overarching research aim.

The first essay provides the foundations for much of the thesis, by identifying the livelihoods of households within the study area. With access to a range of on-farm, off-farm, as well as natural resource based livelihood activities, the livelihood activities are highly diverse. Depending on their access to different social, financial, natural, human and physical capital households within the community, households will allocate their time and assets to generating income from various activities (Carney, 2003; Jansen et al., 2006; Nielsen et al., 2013). Similarly, the extent to which households exploit natural resources at subsistence or commercial levels is also heavily influenced by their access to different capital (Adhikari, 2005; Angelsen et al., 2014; Angelsen and Wunder, 2003; Babulo et al., 2008).

As these differences in subsistence or commercial strategies can result in large differences in income, the benefits from CBNRM, and consequently have impacts on the financial equality within the community. The first essay thus focuses on the extent to which the differences in subsistence and commercial strategies exist within the study area, and how these differences impact the role of direct benefits from natural resources and their contribution to improved equality.

The research objectives thus for the first essay are:

(i) To what extent does environmental income improve income equality within the conservancy?

(ii) How is environmental income distributed amongst the different livelihood strategies within the community?

(iii) What factors influence the adoption of livelihood strategies with higher levels of environmental income?

Having identified the different livelihood strategies, the second essay focuses on the indirect impacts of CBNRM via an environmentally extended village social accounting matrix (ESAM). The establishment of a CBNRM can result in an injection of funds, new sources of revenue and alternative livelihood strategies. Such a shift in the structure of the economy can result in both direct and indirect impacts across environment and non-environment based activities (Silva and Mosimane, 2012). The primary concern from a development economics perspective is then how the direct and indirect benefits are then distributed via the interlinked activities of production and consumption (Pyatt and Round, 1985). In understanding these interlinkages it is possible to identify how the natural resources are utilized in different sectors, by which livelihoods, and how this impacts sustainable and equitable economic growth. The research objectives for the second essay are therefore:

(i) To identify the economic contribution of environment and non-environment based activities to the village economy;

(ii) To identify the structural linkages between environmental and non-environmental activities in the village economy; and

(iii) To observe and explain how environmental income distributed across livelihoods and regions within the village economy.

The success of CBNRM however is not only dependent upon the economic structures within the economy; the social institutions are critical to sustained CBNRM success and the licence of managing institutions to continue (Landell-Mills, 2002; Muradian et al., 2010). At the heart of CBNRM is the willingness of all community members to cooperate and adhere to the local rules governing the conservation of natural resources (Fabricius et al., 2007). Yet, many CBNRM areas are moving beyond simple governance of natural resources, and investing in community projects and community infrastructure, built and maintained in partnership with members of the community. However, sustaining cooperation in environments with idiosyncratic and covariate risks may be difficult.

Individually and separately two important points regarding cooperation under the presence of risk have been established in the literature. Firstly, it is known that in risky environments, such as in sub-Saharan Africa, risk aversion decreases the effort and willingness to invest (Binswanger and Rosenzweig, 1986; Hill and Viceisza, 2011; Holden and Lunduka, 2014; Macours, 2013; Yesuf and Bluffstone, 2009). Secondly, conditional co-operators respond negatively to comparatively lower effort or investment levels which result in a negative spiral decreasing cooperation (Chaudhuri, 2011). These two topics however have not been researched simultaneously. Thus the second essay tries to join these challenges in behavioural economics within a CBNRM context. Broadly, the aim is to understand how risk influences the willingness to cooperate amongst households residing in a CBNRM area. Specifically, the third essay focusses on the following objectives:

(i) To understand the impact of risks on an individual's willingness to cooperate;

(ii) To understand whether external interventions that have improved cooperation in risk-neutral settings, such as communication, have a similar impact in the presence of risks; and

(iii) To understand and isolate the impact that simultaneous risks have on effort exertion levels.

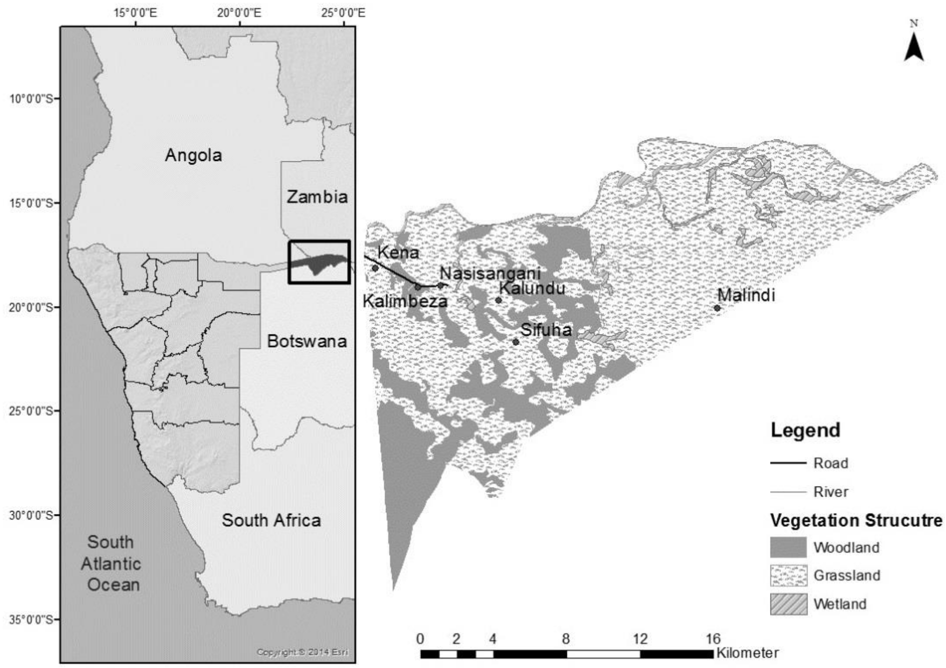
1.3 Data and Study Area

The data for all three essays was obtained from a single CBNRM community in north-eastern Namibia. In selecting the study area an approach similar to that of Suich (2013) was followed. Based on information from extensive discussions with NGOs and experts with many years of experience in the area, the Sikunga Conservancy was selected as the research area for the case study. The conservancy is a registered CBNRM area within Namibia, and had an extremely positive reputation in terms of governance, transparency and equality.

The Sikunga Conservancy is located around 70km from the regional capital in the Zambezi region of Namibia. Covering an area of around 287km^2, the population of around 2000 is spread across 6 villages. With the Zambezi River running north along the conservancy's border, the conservancy benefits greatly from the fish resources in the river and the seasonal flood plains. The wetlands however also provide valuable grazing plains for livestock and rich soils for maize farming. In the slightly higher areas along the southern border the community is endowed with valuable Miombe Woodlands (Mendelsohn, 2010).

The data for the first two essays is based on a household survey conducted in September and October 2012, prior to the beginning of the rain season. 200 households were randomly sampled from households residing within the conservancy. Demographic information as well as detailed economic data on natural-resource and non-natural-resource based activities was collected; including all input costs, all sales, and which agents were involved in the transactions. Time-use data for all family members across the dry, flood, and rain seasons for the previous 12 months was also obtained. Other information on assets, shocks and risks was also collected. Data in this phase was financed by the umbrella programme FONA I (Forschung für Nachhaltige Entwicklung) project, funded by the German Federal Ministry for Education and Research.

Figure 1: Map of Sikunga, its infrastructure and villages



Source: Institute of Environmental Economics and World Trade (2015)

The data for the third essay was collected separately in September and October 2014, and is based on the results of a novel public good game which incorporates aspects of risk as well as real-effort. The experiment design builds on two current features in experimental economics. Firstly, it has been increasingly shown that individuals behave differently in experiments when they are given endowments by researchers, as opposed to when they participate with money they have earned (Harrison, 2007; Muehlbacher and Kirchler, 2009). This has led to an increase in the number of experiments that include real-effort tasks for participants to earn their endowment. In the context of public goods experiments, real effort tasks have taken the form of hurdle tasks, to earn their initial endowment (Cherry et al., 2005), or repetitive tasks required to contribute to the public good (Carbone and Gazzale, 2011; Filiz-Ozbay and Ozbay, 2014). However, whilst only requiring participants to invest effort in the public good, with no effort required for the private good, they are creating a bias in the marginal per capita return for the private and public goods. The novel design of the experiment in this thesis thus incorporates an aspect of real effort which is the same for both public and private goods. Furthermore, the real effort task is one of only a handful that has been implemented with rural-poor communities outside the laboratories of universities. The second novel aspect is the incorporation of risk. Two-player games have shown that "other regarding behaviour" decreases when risk is present (Dana et al., 2004; Exley, 2015; Haisley and Weber, 2010; Karni et al., 2007; Krawczyk and Le Lec, 2010). However, in repeated social dilemmas, the literature is more scarce. To date, social dilemmas incorporating risk have only placed risk on either the public or private good accounts (Cherry et al., 2015; Gangadharan and Nemes, 2009). This again changes the relative returns to the private and public good. Therefore the second novel aspect of the experiment design is to include an idiosyncratic risk to the private good for individuals, and a covariate risk to the public good for the group, where the probabilities for the private and public risks were the same.

The experiment was conducted in September and October of 2014 and was funded under the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) initiative, which was financed by the German Federal Ministry of Education and Research. A separate sample of 200 households were again randomly sampled, although there was some partial overlap with households from the 2012 visit region. The data from the experiment comprises of two sequential games each consisting of 10 rounds.

In addition to the experiment data collected in 2014 two shorter surveys were conducted before and after the experiment. A small survey on willingness to take risks was administered prior to the experiment, and a more detailed survey on behavioural, belief and psychological traits, as well as socio-economic information such as income sources and livelihood strategies was collected following the experiment.

1.4 Methods

Following our detailed case study approach, the methods outlined below build on one another to provide a detailed picture of the economic and social structures within our study area.

In essay one, the primary concern is to identify the mix of activities that homogenous groups adopt as part of their livelihood strategy. The approach, based on Nielsen et al. (2013) and Jansen et al. (2006), uses inputs and time allocation variables as part of a cluster analysis and best reflects resource allocation decisions in line with the sustainable livelihoods framework. A two-step cluster analysis was employed due to its objective decision criteria in determining the number and size of clusters (Mooi and Sarstedt, 2011). Once the livelihood clusters had been identified, the impact of asset groups on the adoption of different livelihood strategies was analysed using a multinomial logit regression, as is common practice in livelihood analysis (Babulo et al., 2008; Barrett et al., 2001; Brown et al., 2006; Faße and Grote, 2014).

In the second essay, the livelihood strategies identified in essay one are incorporated as the basis for institutions in constructing an environmentally extended social accounting matrix (ESAM). Social Accounting Matrices (SAM) are an established modelling method, which became increasingly popular with development planning in the 1980s (Pyatt and Round, 1985). However, this standard approach to SAMs is simply the point of departure. In this thesis several modifications to the matrix structure have been made, whilst remaining consistent with the international System of National Accounts (United Nations, 2014), to construct an ESAM. The ESAM contained within this thesis is the first at a village-level that also incorporates multiple environmental resource accounts. A handful of village-level ESAMs have incorporated a single environmental resource, such as soil degradation (Shiferaw and Holden, 2000) or forest resources (Faße et al., 2014). The village-level ESAM contained in this thesis however has a variety of environmental accounts for fish, forest resources, land-clearing, thatching grass and river reeds. These natural resources form the basis for the environmental activities in a CBNRM economy; furthermore, the ESAM herein is the first for a CBNRM economy.

Once the ESAM was constructed, the impacts on the different livelihoods and regions of the conservancy from various exogenous changes in the economy was analysed via constrained multiplier analysis. This is yet another departure from village-level SAMs, where unconstrained multipliers are often used. However, constrained rather than unconstrained multiplier analysis is used, as natural capital and resources are limited and production cannot be readily increased or decreased depending on demand. Furthermore, unconstrained multipliers tend to overestimate changes in demand (Breisinger et al., 2010; Haggblade et al., 1991; Round, 2003).

The uniqueness of the third essay lies in the quality and novelty of the data, which enables the application of robust yet common econometric methods. Given that the experiment data follows panel form, and following the call of Harrison (2007), the data is analysed using the appropriate econometric models which can account for the structure of the data. Rather than relying on simple non-parametric tests of means between the different treatment groups, a generalised least squares model with individual random effects and group fixed effects, is employed to analyse the impact of risk on cooperation levels. The model is based on Croson (2007). However, as the research question also focused on effort levels in the presence of risk, a Poisson random effects regression, again with group fixed effects is implemented. The Poisson model was necessary as the effort levels follow a count-data structure.

1.5 Results

In the first essay, the primary interest is the impact and role of environmental income across different livelihoods within the study area. Aggregate analysis shows that environmental income improves income equality within the community, as shown by decreases in Gini coefficients and straightening of the Lorenz curves. This result is consistent with literature on forest income from around the world, which also shows it improves equality (Angelsen et al., 2014). However, when looking at the impact across the different livelihoods, the picture is different.

Four livelihood strategies are initially identified: Diversified Low-input Low-output Rural workers, Natural Resource and Agricultural Workers, Skilled Off-farm Workers, and Asset and Cash Rich households. Environmental income is largely concentrated in two livelihood strategies: Natural Resource and Agricultural Workers, and Asset and Cash Rich households. Natural Resource and Agricultural Workers actively harvest forest and fish resources for commercial reasons, and income from harvesting natural resources consists of around 40% of their total income. Income from fish and timber resources for the Asset and Cash Rich households is small in terms of percentages (under 10%), yet the second highest of all livelihood strategies in absolute terms, despite this cluster having more than three times the income of the poorest household cluster.

The access to livestock, physical and financial capital appears to impact the ability to generate income from natural resources, as does gender. Female-led households tend to be excluded from the lucrative fishing sector, and are often exploited in their attempts to engage in the trade of fish (Béné and Merten, 2008).

The second essay was primarily focused on understanding the interlinkages between natural resources across different sectors, livelihoods and regions, and how this impacts economic growth. The structural linkages however indicate that the state of the economy is not equitable, and ecologically unsustainable. The economic contribution of environmental resources represents around 96% of the economic production in the study area, the vast majority of which is due to an increase in forest resources. Of the non-environmental production activities in the study area, livestock and maize farming are the largest contributors.

The environment and non-environment sectors seem to be relatively separate from one another; effectively operating in a two-speed economy. Non-environmental activities, such as tourism and farming are linked with one another, but not with environmental activities, whilst extractive environmental industries such as fishing, firewood, reed and grass collection are strongly inter-linked with one another, but not with non-environmental activities such as tourism or farming.

The use of natural resources as inputs for production within the conservancy exceeds natural growth rates, or is undertaken in such a manner that the natural capital is likely to be rapidly degraded. The valuable fish capital is caught and exported to other regions for short-term gains, whilst slash and burn farming threatens the existing forestry capital.

The structure of the economy is currently heavily biased towards the wealthy households and those who reside near the main road in and out of the conservancy. Households located in villages closer to the road and the river benefit far greater proportionally from exogenous increases in income than the more isolated households further inland in the conservancy. The multiplier analysis also indicates that CBNRM driven sectors, are pro-rich rather than pro-poor, which is contradictory to the CBNRM concept.

Finally, the third essay provides some informative details regarding the behaviour of households when faced with social dilemmas in the presence of risk. The results of the experiment show that when idiosyncratic and covariate risks are present in a public good game, individuals become more selfish and are willing to cooperate less. Furthermore, as expected, when risk is present they are also willing to invest less effort, despite the expected payoff being the same as in risk neutral settings. What is further of concern, is that the experiment also showed that interventions such as communicating with other group members, which has a positive effect in risk-neutral settings, has no effect when risk is present. These changes in cooperation in the presence of risk are a negative indicator for how households may cooperate in the long-term in CBNRM, where the returns to their cooperation in CBNRM are risky and uncertain.

1.6 Outline

The three essays are organised in the order presented in the previous sections. Chapter 2 contains the first essay “CBNRM and the inequality of environmental income: Case study from a Namibian conservancy” that was submitted to Development Southern Africa (2017). Huon Morton collected the data, conducted the analysis and wrote the essay. Ulrike Grote performed a supervisory role and suggested improvements in the manuscript.

Chapter 3 contains the second essay “Evaluating the role of natural resources in a community based natural resource management economy: The case of a Namibian conservancy” that was published by the Journal of Environment Development (2016). Huon Morton collected the primary and secondary data, constructed the model and wrote the essay. Ulrike Grote performed a supervisory role, whilst Etti Winter provided suggestions on aspects regarding the model.

Chapter 4 contains the third essay "The effect of idiosyncratic and covariate risk on the provision of public goods: a real effort experiment from Namibia". Huon Morton designed the experiment, collected the data, constructed the econometric models and wrote the essay. Ulrike Grote performed a supervisory role, whilst Etti Winter provided suggestions regarding the experiment design.

Table 1 provides and overview of the essays.

Table 1: Overview of Essays

	Title	Authors	Presented / Published / Submitted
Chapter 2	CBNRM and the inequality of environmental income: Case study from a Namibian conservancy	H. Morton, U. Grote	Submitted to: *Development Southern Africa* 2017 Earlier version presented at: International Symposium on Society and Resource Management (ISSRM), Hannover 8-13 June, 2014
Chapter 3	Evaluating the role of natural resources in a community based natural resource management economy: The case of a Namibian conservancy	H. Morton, U. Grote, E. Winter	Published in: *Journal of Environment and Development, 2016, Vol. 26, Issue 4, 396-425*
Chapter 4	The Effect of Risk on Cooperation and Effort: A Lab-in-the-field Experiment	H. Morton, U. Grote, E. Winter	Submitted to: *Environmental and Development Economics 2018* Earlier version presented at: Verein für Socialpolitik PhD Colloquium, Zurich, 11-12 November, 2015 14th EUDN PhD Colloquium, Paris, 26-27 November 2015

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2 CBNRM and the Inequality of Environmental Income: Case Study from a Namibian Conservancy

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ABSTRACT

Equitable outcomes are central to the sustained success of community-based natural resource management (CBNRM) and are increasingly embedded in the principles and laws that establish CBNRM programmes. To date, research has focussed on the equitable distribution of direct financial benefits, primarily from tourism and game hunting. However, there has been little consideration of the equitable distribution of the most valuable resources in CBNRM, natural resources, and the environmental income which can be generated from their harvest. Using detailed survey data from 200 households in a conservancy in northeastern Namibia, we evaluate how environmental income generated from natural resources contributes to equitable outcomes across four unique livelihood strategies. Overall, environmental income equality within the community improves. However, environmental income tends to remain out of the reach of asset-poor households and has little impact on the structural inequality.

2.1 Introduction

Equitable distribution of benefits is central to sustained and successful community-based natural resource management (CBNRM) (Berkes, 2004; Brooks et al., 2013; Cox et al., 2010; Hoole, 2009; Kellert et al., 2000; Nkhata and Breen, 2010; Pagdee et al., 2006). Community concerns regarding the distribution of financial and natural resources can lead to the unexpected undermining of CBNRM communities (Mosimane and Silva, 2015; Riehl et al., 2015; Suich, 2010). The success of CBNRM, particularly in Namibia, has been trumpeted because of its improvement of environmental sustainability and economic growth (Naidoo et al., 2011; Roe et al., 2009). However, despite it being central to successful CBNRM programmes, the equitable benefit distribution in CBNRM communities has tended to receive less attention (Gibbes and Keys, 2010). When equitable outcomes have been studied, the focus has tended to be the distribution of cash benefits (Mulonga and Murphy, 2003) or access to CBNRM-associated jobs such as in tourism (Ezebilo and Mattsson, 2010; Kanapaux and Child, 2011; Lapeyre, 2010; Libanda and Blignaut, 2008). However, the what communities consider a benefit distribution can be much broader than simply cash or even employment; thus, problems with inequitable access to natural resources and environmental income can escalate to become an issue within the community (Cochran and Ray, 2009; McDermott et al., 2013).

Environmental income is the “value added in alienation or consumption of natural capital within the first link in a market chain, starting from the point at which the natural capital is extracted” (Sjaastad et al., 2005, p. 45). More simply, it is the value of products harvested or processed from natural resources that are sold, or used for household subsistence consumption. The value of environmental income within CBNRM areas is much higher than that from tourism and game hunting (Turpie et al., 2005), and at a macro-level, environmental income has been shown to improve income equality (Angelsen et al., 2014). However, environmental income is still not included as a standard item in all household surveys (Grosh et al., 2000; Walelign et al., 2016) despite the fact that it has consistently been demonstrated that where environmental income is not included in household income accounts, estimates of rural poverty levels and inequality results can be misleading and inaccurate (Cavendish, 2000; Vedeld et al., 2007; Walelign et al., 2016).

Including environmental income in household accounts in income equality assessment is critical. As the ability of households in rural communities to generate environmental income heavily influenced by their asset mix (Angelsen et al., 2014; Angelsen and Wunder, 2003; Babulo et al., 2008; Faße and Grote, 2014; Purvis, 2002; Torpey-Saboe et al., 2015), any analysis of equality needs to move from the macro-level down to household units and their livelihood strategies. The importance of analysing equality at the household level is further reinforced by the growing evidence that the costs and benefits of community-wide conservation interventions such as CBNRM impact different livelihood strategies to differing degrees (Collomb et al., 2008; Pascual et al., 2010; Pienaar et al., 2013; Scanlon and Kull, 2009; Silva and Mosimane, 2012; Sommerville et al., 2010; Suich, 2013).

As part of a broader project investigating the role of natural resources in the village economy of conservancies, we were interested in how environmental income is distributed within a conservancy. We partnered with local non-government organisations (NGOs) and a conservancy in the Zambezi region of northeastern Namibia to collect detailed survey data from 200 households within the conservancy to answer the following research questions: (i) To what extent does environmental income improve income equality within the conservancy? (ii) How is environmental income distributed amongst the different livelihood strategies within the community? (iii) What factors influence the adoption of livelihood strategies with higher levels of environmental income?

Our approach follows four main steps. Initially, we follow the approach of Angelsen et al. (2014) and evaluate the impact of environmental income on income equality using Gini coefficients and Lorenz curves. In a country with a high Gini coefficient and heterogeneous livelihoods, a disaggregated analytical approach is required; thus, we next follow the similar approach of Walelign (2016) and Nguyen et al. (2015) and apply a two-step cluster analysis to identify different livelihood strategies within the community. We then compare the contribution of environmental income to each livelihood strategy to identify whether environmental income is achieving improved income equality at a livelihood level. Finally, we conduct a multinomial logit analysis to identify potential barriers that prevent households from benefiting more from environmental income.

2.2 CBNRM in Namibia

The nation-wide programme of conservancies in Namibia, which began in the 1990s (Hoole and Berkes, 2010), is one of the most well-regarded CBNRM programmes in the world (Boudreaux and Nelson, 2011). By registering as a conservancy, communities can gain the rights to benefit directly from the natural resources within their registered geographical boundaries. They can exclude individuals from outside the community from harvesting resources from within their boundaries and establish rules regarding natural resources that members of the community have a direct incentive to follow.

In the Namibian CBNRM context, financial and non-financial benefits provide an incentive for a more sustainable management of natural resources (Silva and Mosimane, 2012). In registering as a conservancy, a community must document and submit to the government an 'equitable benefit distribution plan' (Mulonga and Murphy, 2003). The equitable benefit distribution plan must describe how the conservancy management committee will share the financial and non-financial benefits with members of the community (Jones and Murphree, 2004). Overall, the equitable distribution plans tend to focus heavily on the financial benefits from the sale of hunting licences and fail to consider the broader distribution of natural resources (Mulonga and Murphy, 2003).

2.3 Conceptual Framework and Key Definitions

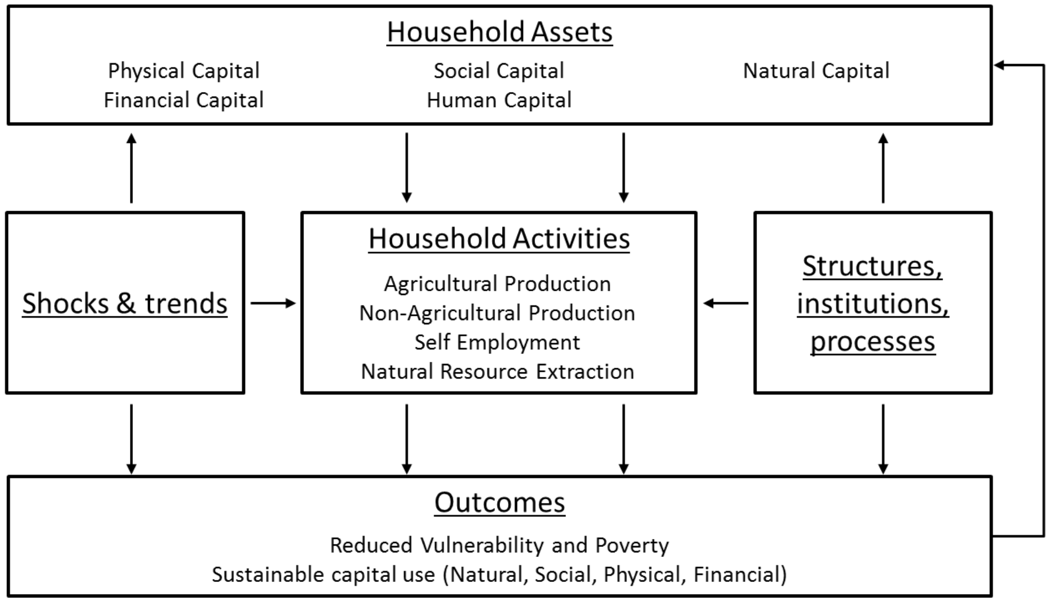
2.3.1 Conceptual Framework

The conceptual framework that we apply is the Sustainable Livelihoods Framework (SLF). The SLF highlights the factors that influence a household's chosen livelihood strategy and the outcomes it can achieve (Scoones, 1998). The framework consists of five major components: the assets households have access to; the activities the households allocate their assets to; the outcomes their activities deliver; the structures, institutions and processes that govern the household's assets, activities and outcomes; and finally, the shocks and trends that can disrupt or change asset mixes, activity choices and/or outcomes (see Figure 2) (Carney, 2003).

At the core of the framework are the five asset types (natural, human, physical, social and financial capital) that households deploy for various activities in order to generate income (Babulo et al., 2008; Carney, 2003). The mix of activities is defined as a household's livelihood strategy (Scoones, 1998). The framework has regularly been used to help identify homogeneous livelihood strategy groups by focussing on the five asset types and their activity mix (Faße and Grote, 2014; Jansen et al., 2006; Nguyen et al., 2015; Nielsen et al., 2013; Rayamajhi et al., 2012; Soltani et al., 2012). We build on this long tradition and utilise the framework in a similar way.

Whilst acknowledging that shocks and trends as well as structures, institutions and processes influence livelihood strategies and their outcomes, our focus remains on the identification of livelihood strategies and the extent to which environmental income improves income equality among different strategies. How we operationalise the definition of livelihood strategy is outlined in section the Method section.

Figure 2: Conceptual Framework



Source: Own illustration adapted from Babulo et al. (2008) and Carney (2003)

2.3.2 Key Definitions

2.3.2.1 Total Net Income and Environmental Income

We define total net income as income from employment; net income from agriculture; net income from non-agricultural self-employment and remittances, as is common (Johnson, 1990); and net environmental income. Net income from agriculture and non-agricultural self-employment is exclusive of input costs, but inclusive of household labour. The inclusion of environmental income as a unique source of income requires clear boundaries to distinguish between it and other sources of income, such as agriculture and non-agricultural self-employment (Sjaastad et al., 2005). For example, if a household catches and sells fish, is this considered self-employment or environmental income? What if the fish were caught from a local fish farm? Environmental income therefore has additional key components:

1. It includes natural resources harvested from wild sources and thus excludes plantation forests or fish farms; and
2. It is restricted to natural resources within the first link of a value or market chain, beginning from the point of extraction. Therefore, income from catching wild fish and selling them to a wholesaler would be defined as environmental income. The income of the wholesaler, who may then dry the fish and sell it to other customers, is not counted as environmental income (Sjaastad et al., 2005), the wholesaler's income would be considered self-employment.

We use value added instead of rent as the value of income, as the cost of capital and opportunity cost of labour are so low that rent can be considered equivalent to value added (Babulo et al., 2008; Sjaastad et al., 2005). It was also more accurately captured within the data set. In conclusion, environmental income is defined as the value added of natural resources within the first link of the market chain minus input costs but inclusive of household labour (Babulo et al., 2008; Sjaastad et al., 2005; Walelign, 2016).

The value calculated for environmental income was based on detailed household survey data which included the total value, unit value and total number of units harvested, processed and sold.

2.3.2.2 Equitable outcomes and Equality

In discussing the issues of equitable outcomes and equality, it is important to note the difference between the two concepts, which are both associated with the notion of distributive justice. We define the concept of equality, as where the size of all portions are the same (Konow, 2003). We refer to this both in the distribution of environmental income, and the distribution of total income amongst all households.

The concept of equitable outcomes needs to be considered from two perspectives – the accountability principle and the needs principle. The accountability principle is based on the concept of merit, where rewards reflect the inputs (Leventhal, 1980). The needs principle is based on the idea that those that are most disadvantaged would receive the largest portions (Konow, 2001).

Both principles in the context of CBNRM are ethically justifiable (Pascual et al., 2010). The accountability principle was the concept behind establishing CBNRM, so that the communities who bear the costs of providing and stewarding natural resources benefit from the same resources (Murphree, 1993). But operationally, this becomes difficult to establish on an individual household level within CBNRM. Furthermore, it reflects competitive contexts where the individual is prioritised, and all can compete on a fair basis. However, where it is the collective community who must work together, the accountability principle can create disharmony (Mohammed, 2011).

In the context of conservancies, we expect that not all households are able to compete equally for the same environmental income sources. Furthermore, as the community must work collectively to protect and preserve the natural capital which generates environmental income. If competition for these resources was actively encouraged, it may threaten the sustainability of the natural capital (Röttgers, 2016).

As the accountability principle is likely to conflict with the context and objectives of the community in our study area, and the needs principle aligns with the pro-poor objectives when we discuss equitable distribution, we follow the needs rule of distributive justice, and define equitable outcomes as those where the poorest households would benefit the most from environmental income (Konow, 2001), which in turn would lead to greater income equality.

2.4 Study Area and Data

2.4.1 Study Area

Our study was conducted in the Sikunga Conservancy, located approximately 70 km from the regional capital (Katima Mulilo, population ~30,000) in Zambezi region of northeastern Namibia. Consisting of six villages spread across 287 km^2, the conservancy contains approximately 440 households and a population of approximately 2000.

To select an appropriate conservancy for a case study, we partnered with several local NGOs and followed an approach similar to that of Suich (2013). The selection criteria for the case study were based on the perception by experts and practitioners that it would be successful in implementing fair and transparent governance systems to manage the conservancy.

The management of natural resources within the Sikunga Conservancy is complex. Access to wild and large game in Sikunga is fully restricted. Access to thatching grass and river reeds is partially restricted via licensing schemes, whilst access to grazing land and firewood is unrestricted. However, the conservancy and its members have an incentive to develop and agree rules to manage grazing land and firewood. These resources form the foundations of wild habitat for the game which generate the bulk of the conservancy's cash income. The management of fish within the conservancy is multifaceted, with fishing licences granted by government ministries, the conservancy has recently taken an active role in enforcing fishing licences and standards.

Deforestation in the region is ~1.3%, and factors such as population growth and cattle farming may cause it to increase if not managed properly (Palmer and MacGregor, 2008). The conservancy is looking to further enhance its ability to restrict deforestation by registering as a Community Forestry zone, which would give it greater powers to set rules regarding the use of forest resources. Overfishing and a lack of coordinated management have led to dwindling fish stocks (Tweddle et al., 2015).

Increasing livestock head counts, deforestation and slash-and-burn farming have contributed to the erosion and degradation of the floodplains in the Zambezi region (Purvis, 2002). Farmers slash and burn land to either clear it for conversion to crop land, or to generate new-growth to feed their cattle. Whilst the value of the land use for agriculture compared with tourism may be marginal (Nelson et al., 2010), households continue to convert land, which restricts conservation opportunities (Norton-Griffiths, 2007).

Natural resources form a large portion of the livelihood strategies in the Zambezi region. Women often are found to harvest thatching grass and river reeds as well as small, producing nature-based crafts (Ashley and LaFranchi, 1997; Kanapaux and Child, 2011; Purvis, 2002). Catching, drying and trading fish is part of the region's cultural identity (Tvedten, 2002), though not all households have access to fish to the same degree due to social, financial and physical barriers (Purvis, 2002). There is also a gender bias in fishing, with men catching and women often drying and selling the fish (Purvis, 2002; Tvedten, 2002). Forest resources are used mostly for fuelwood (Barnes, 2013).

Agriculture practices are fairly rudimentary “low-input, low-output” approaches (Ashley and LaFranchi, 1997), whilst livestock herding is viewed as a form of investment and saving (Barnes, 2013).

Off-farm income opportunities are usually linked to tourism or government jobs, and a high number of households also receive social welfare payments such as pensions and orphan payments (Kanapaux and Child, 2011; Suich, 2010).

2.4.2 Data

A household list was obtained containing all the households of the six villages within the Sikunga Conservancy. A non-stratified sample of 200 (45%) households was selected. As it was non-stratified, the portion of respondents reflects the relative size of the population of each village, and our results are representative of the population of Sikunga at 95% confidence intervals. We do not report results at the individual village level, as without stratification, the sample sizes for smaller villages cannot be considered statistically representative of each village. One observation was removed from the sample, as the household member completing the survey did not regularly reside with the family in Sikunga and was only temporarily visiting the area. The survey was conducted in September and October 2012 and captured information on income sources, time use, consumption and expenditure data, harvesting of natural resources and livestock and crop management. Information about each household’s socio-demographics and social capital was also collected. The relevant data can be made available to interested parties on request.

There is no census data for our study area; however, the average income and income sources are comparable to the findings of other research within the region and the relevant time frames (Mendelsohn et al., 2012; National Statistics Agency, 2012; Silva and Mosimane, 2014).

2.5 Method

2.5.1 Cluster Analysis: Identifying Unique Livelihood Strategies

Early attempts to operationalise the definition of a livelihood strategy used income percentiles to see how asset mixes and income sources changed from the wealthiest to the poorest (Nielsen et al., 2013).

However, this approach was criticised because income is a measure of output rather than input (Brown et al., 2006).

Aligning more closely with the SLF, asset-based approaches were subsequently adopted; however, these often failed to capture allocation decisions (Jansen et al., 2006). To this end, an activity-based approach to livelihood strategy identification provided a more accurate picture of how households utilise their assets (Nielsen et al., 2013).

Our approach was based on Jansen et al. (2006) and Nielsen et al. (2013), using labour and input costs to identify livelihood strategies. Our activity and input-based variables were (1) inputs purchased for crop activities; (2) inputs purchased for livestock activities; (3) hours allocated to self-employment; (4) hours allocated to agricultural work; (5) hours allocated to collecting natural resources; (6) hours allocated to off-farm, non-agricultural work; and (7) transfers from government, NGOs, family and friends. Descriptive information on these variables can be found in Table 3 in the results section.

We used the two-step cluster method, as it utilises objective Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) to determine the appropriate number of clusters and is an improvement on the K-means and hierarchical clustering methods (Mooi and Sarstedt, 2011). We conducted the analysis using log-likelihood to calculate the distance between clusters and compared the results of both AIC and BIC regarding the number of clusters.

2.5.2 Multinomial Logit Model: Identifying Determinants of Environmental Income-based Livelihoods

The analysis of income components and Gini coefficients helps identify which livelihoods depend the most on environmental income; however, it is unable to identify the factors that influence adopting a livelihood strategy that incorporates environmental income. To do this, we run a multinomial logit regression. As is common in livelihood analysis, we analyse the natural, human, physical, financial and social capital that may enable or inhibit livelihood choices rich in environmental income (Babulo et al., 2008; Brown et al., 2006; Faße and Grote, 2014; Jansen et al., 2006).

The reference group is based on which livelihood strategy benefits the most from environmental income. Using the maximum likelihood approach, our estimation strategy follows (Train, 2009):

$$Pr_{ni} = \frac{\exp(\beta\prime x_{ni})}{\sum_{j=1}^{J} \exp(\beta\prime x_{nj})} \qquad (1)$$

where Pr is the probability of household n choosing livelihood strategy alternative i compared to the base category $\mathrm{j} = 1$, and x is a vector of natural capital (minutes to firewood, village located near river); human capital (age, education and gender of household head, household size and number of adults of working age who did not graduate from secondary school, graduated from secondary school and graduated from university); physical capital (hectares under cropping, value of assets and value of livestock); financial capital (total savings); and social capital (trust) variables. The probability of household n choosing the baseline category is further given by:

$$Pr_{nj} = \frac{1}{1+\sum_{j=1}^{J} \exp(\beta\prime x_{nj})} \tag{2}$$

2.6 Results

2.6.1 The Contribution of Environmental Income to Equality

Namibia has a relatively high Gini coefficient, and the Zambezi region reflects this. In 2010, the mean per capita income for the Zambezi region was NAD$7,198 (PPP$4,318) with a Gini coefficient of 0.59 (National Statistics Agency, 2012) (see Table 2).

Table 2: Gini Coefficient for Different Income Sources

Source	National Statistics Agency (2012)	Own Data (sourced 2012)				
	Income[1]	**Total Income**	**Total Income without Fish**	**Total Income without Firewood**	**Total Income without Fish and Firewood**	**Environmental Income (Fish and Firewood)**
Gini Coefficient	0.59	0.497	0.513	0.539	0.564	0.673

Source: National Statistics Agency (2012); Sikunga Survey Data 2012; own calculations

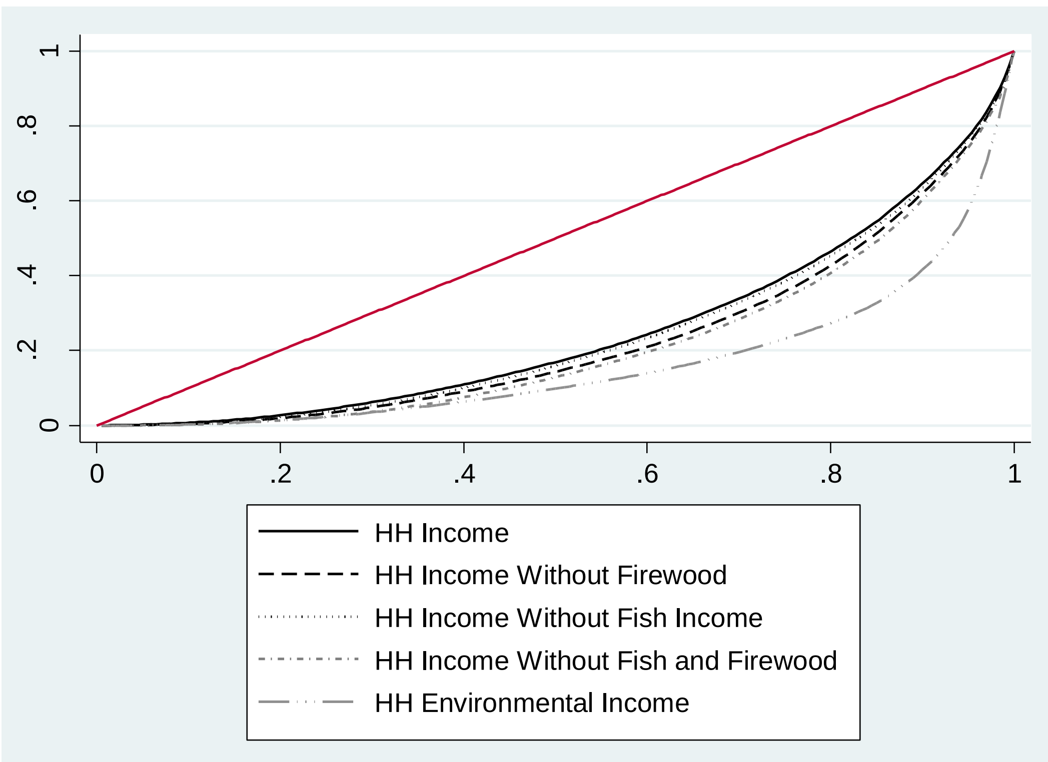
When calculating the Gini coefficient, including all non-environment and environment income sources, we obtain a Gini coefficient of 0.497. However, when we start calculating the Gini coefficient without the contribution of environmental income, we see that inequality worsens.

Income inequality would worsen by approximately 3% without income from fish, by approximately 8% without income from firewood and by approximately 12% without all environmental income sources.

[1] Income calculated by the National Statistics Agency in Namibia excludes environmental sources of autonomous consumption and therefore excludes the value of environmental income from fishing and firewood collection.

By observing the Lorenz curves, we can see that environmental income is unequally distributed amongst the households (Figure 3). Following the line "HH Environmental Income," we observe that approximately 20% of the households obtain almost 70% of their environmental income within the conservancy, although it is difficult to ascertain whether a particular livelihood strategy benefits from this. It is therefore important to move beyond income quintiles and to look more closely at the livelihood strategies within the conservancy to identify whether the unequal distribution of environmental income is indeed equitable and thus aligned with the goals of CBNRM.

Figure 3: Lorenz Curves for Sikunga Households With and Without Environmental Income



Source: Sikunga Survey Data 2012; own analysis

2.6.2 Environmental Income and Equality Across Heterogeneous Livelihoods

Our cluster analysis identified four unique livelihood strategies within Sikunga that involve investing resources (Table 5) in distinct activities, which then generate unique portfolios of income (Table 4). The number of clusters was consistent with both AIC and BIC selection. Looking briefly at the variables used to cluster our households (Table 3), we see that the four clusters can be defined by a small number of features.

Cluster 1 can be identified by the low input costs and low productive hours invested across all livelihood activities. We refer to cluster 1 as Diversified Low-input, Low-output Rural Workers. Cluster 2 invests the highest number of hours in extracting natural resources but with the majority of its working time allocated to on-farm work. We refer to cluster 2 as Natural Resource and Agricultural Workers. Cluster 3 allocates the majority of time to skilled, high-paying, off-farm employment. We refer to this cluster as Skilled Off-farm Workers. Cluster 4 is defined by high input costs for livestock and high transfers from government. Households in this cluster also invest significant time in off-farm work, despite their high income from private pensions. We refer to this cluster as Asset and Cash Rich. In all livelihood strategy clusters, households invest their resources across activities to varying degrees, and no cluster adopts a pure strategy, as is common in rural livelihoods (Ellis, 1998).

Table 3: Distribution of Variables Used for Cluster Analysis Across the Four Clusters

	Cluster 1 *(Diversified Low-input, Low-output Rural Workers)*	**Cluster 2** *(Natural Resource and Agricultural Workers)*	**Cluster 3** *(Skilled Off-farm Workers)*	**Cluster 4** *(Asset and Cash Rich)*
Number of Households	97	49	29	24
Purchased inputs for crop activities	$ $44^{2,3,4}$	$ 91^{4}	$ 86^{4}	$ 509
Purchased inputs for livestock activities	$ $232^{2,3,4}$	$ $1,385^{4}$	$ 846^{4}	$ 4,873
Hours allocated to Self-employment	17^{3}	22^{3}	$1,076^{4}$	13
Hours allocated to agriculture work	$498^{2,4}$	$1,736^{3,4}$	718	960
Hours allocated to collecting natural resources	$110^{2,3}$	$658^{3,4}$	65	94
Hours allocated to off-farm, non-agricultural wage work	$485^{2,3,4}$	$184^{3,4}$	$3,671^{4}$	1,085
Transfers from government, NGOs, family and friends	$ $3,216^{3,4}$	$ $3,145^{4}$	$ $1,579^{4}$	$ 11,539
Total Productive Hours	$1,110^{2,4}$	$2,600^{2,4}$	$5,530^{4}$	2,152

2,3,4 indicate that the mean is significantly different at alpha=0.10. 2 indicates significantly different to cluster 2, 3 significantly different to cluster 3, and 4 significantly different to cluster 4. All variables were tested with the Mann-Whitney U-test. Source: Sikunga Survey 2012; own calculations.

On-farm work contributes only a small proportion of total income (10-14%), whilst transfers and remittances contribute between 9 and 21%. Off-farm wages are an important source of income for all clusters, though this source differs in terms of stability, seasonality and size across each cluster. The contributions of off-farm wages and environmental income vary the most across all livelihood strategies; environmental income contributes between 6 and 44% of income for households, whilst off-farm wage income contributes between 29 and 70%.

Table 4: Comparison of Income Sources Across Each Cluster

	Cluster 1 *(Diversified Low-input, Low-output Rural Workers)*	**Cluster 2** *(Natural Resource and Agricultural Workers)*	**Cluster 3** *(Skilled Off-farm Workers)*	**Cluster 4** *(Asset and Cash Rich)*
Number of Households	97	49	29	24
		On-farm income (NAD$)		
Net Income from Maize	$ 401 [2,4] (2.7%)	$ 878 [4] (2.7%)	$ 754 (2.4%)	$ 1,232 (2.4%)
Net Income from Livestock	$ 1,625 (10.8%)	$ 3,051 (9.4%)	$ 2,343 (7.4%)	$ 3,899 (7.8%)
		Income from natural resources (NAD$)		
Net Income fish	$ 877 [2] (5.8%)	$ 11,184 [3,4] (34.4%)	$ 120 [4] (0.4%)	$ 2071 (4.1%)
Net Income from timber products	$ 2,408 [2,3] (16.0%)	$ 3,876 (11.9%)	$ 1,819 (5.8%)	$ 1,943 (3.9%)
		Wage Income (NAD$)		
Wage income	$5,130 [3,4] (34.1%)	$10,087 [3] (31.1%)	$22,131 [4] (70.2%)	$ 27,751 (55.2%)
		Transfers (NAD$)		
Welfare	$1905 [3,4] (12.7%)	$1836 [3,4] (5.7%)	$869 [4] (2.8%)	$9091 (18.1%)
Remittances	$ 1,311 (8.7%)	$ 1,308 (4.0%)	$ 709 (2.2%)	$ 2,447 (4.9%)
		Other (NAD$)		
Other income (small trade and casual employment)	$ 1,369 (9.1%)	$ 2,087 (6.4%)	$ 2,798 (8.9%)	$ 1,817 (3.6%)
		Total Income (NAD$)		
Total Income	$15,026 [2,3,4]	$34,307	$31,543	$50,251

2,3,4 indicate the mean is significantly different at alpha=0.10. 2 indicates significantly different to cluster 2, 3 significantly different to cluster 3, and 4 significantly different to cluster 4. All variables were tested with the Mann-Whitney U-test. Source: Sikunga Survey 2012; own calculations.

The highest number of households belongs to the Diversified Low-input, Low-output Rural Workers cluster. This cluster also has the lowest average income, with wages, natural resources and remittances almost of equal importance. Households in this cluster rely more heavily on timber and non-timber forest products, consuming almost all of them at home. Diversified Low-input, Low-output Rural Workers tend to sell less than a quarter of the thatching grass and reeds they harvest each year, indicating that resource harvesting is more for autonomous consumption than for generating cash income.

Consisting of 49 households (25% of the sample), Natural Resource and Agricultural Workers generate the most environmental income. These households catch the highest volume of fish of all clusters, approximately 860 kg per year per household. Further reinforcing Natural Resource and Agricultural Workers' use of natural resources to generate income, this cluster also sells the highest volume of reeds (533 kg) and thatching grass (579 kg).

Skilled Off-farm Workers have the highest off-farm income of all clusters, driven by well-paying and stable salaries from off-farm jobs in the government and tourism sectors and with lower absolute levels of environmental income from fish and timber products. Only a small portion (15%; 29 households) of our sample adopted this livelihood strategy.

The Asset and Cash Rich cluster consisted of 24 households. Households in this cluster have the highest levels of welfare, remittances and wage income in the conservancy as well as the highest level of assets. This cluster receives approximately 22% of its income from government and private pensions as well as transfers from relatives. Despite this high cash income stream, the Asset and Cash Rich extract the second-highest volume of fish and sell approximately 60% of their catch for cash income. As the ability of a household to adopt one of the livelihood strategies is influenced by its asset mixes, we look at the differences in the human, physical, financial, and natural capital (Table 5) that each cluster has access to.

Looking at human capital, we see that in terms of labour capacity, Asset and Cash Rich households have the highest number of working adults and the highest number of retirees. In contrast, Diversified Low-input, Low-output Rural Workers appear capacity constrained, as on average, they have the lowest number of household members and the lowest number of adults of working age. Consequently, such households also allocate the lowest number of hours to productive activities in total (1110 hours per year) and per working adult (597 hours per year per adult).

Table 5: Comparison of Human, Physical, Financial, and Natural Capital Across Each Cluster

	Cluster 1 *(Diversified Low-input, Low-output Rural Workers)*	**Cluster 2** *(Natural Resource and Agricultural Workers)*	**Cluster 3** *(Skilled Off-farm Workers)*	**Cluster 4** *(Asset and Cash Rich)*
N	97	49	29	24
Human Capital				
Female Household Head	0.52	0.33	0.24	0.25
Age of Household Head	43.73^{4}	43.77^{4}	39.68^{4}	56.35^{3}
Size of Household	$4.1^{2,4}$	5.2	4.7	5.5
Number of Children (<16 years)	1.82	1.94	1.66	2.17
Number of Pensioners (>60)	0.20^{4}	0.12^{4}	0.10^{4}	0.54
Number of adults of working age who did not graduate from Secondary School (#)	1.27^{2}	2.02^{3}	1.45	1.58
Number of adults of working age who graduated from secondary school (#)	0.52^{3}	0.63	0.9	1.13
Number of adults of working age who graduated from university (#)	0.07^{4}	0.02^{4}	0.10^{4}	0.54
Physical Capital				
Value of Livestock (NAD$)	\$ $6,821^{2,3,4}$	\$ $26,122^{4}$	\$ $13,900^{4}$	$ 63,041
Value of Physical Assets (NAD$)	\$ $1,233^{3,4}$	\$ $1,742^{4}$	$ 2,212	$ 27,710
Value of Cereal Stock in Storage (2012) (NAD$)	\$ 92^{2}	\$ 219^{3}	\$ 78^{4}	$ 289
Financial Capital				
Savings (NAD$)	\$$592^{2,3,4}$	\$ $1,951^{4}$	\$ $2,056^{4}$	$ 15,546
Natural Capital				
Area Slashed and Burned (ha)	0.91^{4}	2.55^{3}	1.00^{4}	2.45
Area Tilled (ha)	1.81^{2}	3.26^{3}	1.66	1.98

2,3,4 indicate that the mean is significantly different at alpha=0.10. 2 indicates significantly different to cluster 2, 3 significantly different to cluster 3, and 4 significantly different to cluster 4. All continuous variables were tested with the Mann-Whitney U-test. Source: Sikunga Survey 2012; own calculations.

Looking at physical capital, we see a clear difference between the wealthier and the poorer households' livelihood strategies. The Asset and Cash Rich cluster owns over 70% of the physical capital in Sikunga yet represents only 12% of households. On average, Diversified Low-input, Low-output Rural Workers have the lowest value of livestock, physical assets and cereal storage. Similarly, in terms of financial capital, Diversified Low-input, Low-output Rural Workers have the lowest savings, and Asset and Cash Rich households, on average, have the highest.

Looking at the area of land cleared through slash-and-burn farming, Diversified Low-input, Low-output Rural Workers clear the smallest areas, whilst Asset and Cash Rich households clear the most.

In summary, we have identified four unique livelihood strategies that depend on different assets to differing degrees and generate significantly different outcomes. Diversified Low-input, Low-output Rural Workers generate very low incomes and rely on small patches of land and forest resources. Natural Resource and Agricultural Workers also have low incomes yet complement their incomes by exploiting natural resources, primarily fish stocks, although they hold high values of livestock and assets. Skilled Off-farm Workers have one of the highest incomes and rely the least on natural resources within the conservancy. Finally, Asset and Cash Rich households, despite having the highest level of assets and income, continue to extract the second-highest levels of natural resources among all the livelihood strategies.

Our descriptive analysis shows that environmental income is unequally and partially inequitably distributed within the conservancy. Environmental income improves economic equality for only one particular livelihood strategy, Agriculture and Natural Resource Workers, which represents only 25% of the households in Sikunga, whilst almost 50% of the households that belong to the poorest Diversified Low-input, Low-output Rural Workers benefit only marginally from environmental income when compared with the absolute environmental incomes of other households.

2.6.3 Determinants of Environmental Income-based Livelihoods

As environmental income appears to be concentrated within specific livelihood strategies, we are interested primarily in identifying which asset types are correlated with livelihood strategies that earn higher levels of environmental income. This may help identify asset barriers that restrict poorer households from gaining more from environmental income and thus help inform potential policy interventions. We use the Natural Resource and Agricultural Workers cluster as the reference category, as these households earn the highest amount of environmental income. The results from the multinomial logit regression model are presented in Table 6.

The results show that female and older household heads are less likely to adopt a livelihood strategy based on environmental income. Second, human capital and labour capacity are correlated with higher levels of environmental income, as households with a higher number of (uneducated) working adults are more likely to adopt livelihood strategies based on environmental income. Similarly, increased land size and savings are also correlated with higher levels of environmental income.

Table 6: Multinomial Logit Regression

Reference Group: Natural Resource and Agricultural Workers	*Diversified Low-input, Low-output Rural Workers*		*Skilled Off-farm Workers*		*Asset and Cash Rich*	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Female Household Head	0.9490*	0.5615	-0.3399	0.6724	-0.1002	0.9536
Age of Household Head	0.0490*	0.0257	-0.0078	0.0312	0.0419	0.0340
Education of Household Head	0.0344	0.1075	0.0675	0.1336	-0.1044	0.1442
Size of Household	-0.2501	0.1613	-0.1203	0.1847	0.4758	0.3057
Number of adults of working age who did not graduate from Secondary School (#)	-0.8519***	0.3284	-0.3891	0.3773	-0.5564	0.5091
Number of adults of working age who graduated from secondary school (#)	-0.2399	0.3552	-0.0441	0.4347	-1.5203*	0.8201
Number of adults of working age who graduated from university (#)	0.8335	1.4715	-1.3401	6.5167	1.7850	2.4307
Hectares under Cropping	-0.4875***	0.1206	-0.2842*	0.1654	-0.2659	0.1920
Value of Assets	-0.0000	0.0001	0.0001	0.0001	0.0003**	0.0001
Value of Livestock	-0.0000*	0.0000	-0.0000	0.0000	-0.0000	0.0000
Total Savings	-0.0002**	0.0001	0.0000	0.0001	0.0002**	0.0001
Trust	-0.2877	0.2949	-0.1521	0.3414	0.4447	0.4840
Minutes to Firewood	-0.0006	0.0058	0.0051	0.0067	0.0121	0.0083
Village located near river and infrastructure	-0.6885	0.5445	1.3870*	0.7709	0.3465	0.9655
Constant	3.1532*	1.8538	0.1546	2.2612	-5.5735*	3.2249

Pseudo R^2=0.36 Likelihood Ratio: 132.17
*Note: *=Significant at 0.1 confidence level; **=Significant at 0.05 confidence level; ***=Significant at 0.01 confidence level.*
Source: Sikunga Survey 2012; own calculations.

2.7 Discussion

Overall, we find that environmental income improves equality within Sikunga. The contribution of environmental income to equality is greater in Sikunga than is generally found in Africa (Angelsen et al., 2014), though it may reflect the extreme inequality in Namibia and the Zambezi region.

The improvement in overall equality is driven largely by a single livelihood strategy that generates high levels of environmental income: harvesting wild fish stocks. Natural Resource and Agricultural Workers have a lower proportion of female household heads and higher levels of physical and financial capital when compared to Diversified Low-input, Low-output Rural Workers – the poorest of all livelihood strategies. As equitable benefit distribution is both a core principle of CBNRM and a condition for long-term success (Berkes, 2004; Brooks et al., 2013; Brown, 2002; Cox et al., 2010; Hoole, 2009; Kellert et al., 2000; Nkhata and Breen, 2010; Pagdee et al., 2006), it is a matter of concern that approximately 50% of the poorest households do not appear to be achieving a greater increase in income equality through environmental income or participation in CBNRM.

It also appears that for one livelihood strategy, environmental income is actually enhancing inequality. Asset and Cash Rich households earn 22% more from environmental income than the poorest Diversified Low-input, Low-output Rural Workers households, yet they have the highest values of physical and financial capital. The high volumes of fish extracted by this cluster contrast with the common assumption that poorer households are responsible for overfishing and environmental degradation (Dasgupta et al., 2005). That the wealthy households are exploiting the most valuable resources2 indicates that the conservancy institution may not be contributing to equality as much as it could, as some sources of environmental income are not only unequally but also inequitably distributed. This goes against the economic equity goals of CBNRM and could lead to social unrest in the future.

The results from our multinomial logit indicate that a lack of human and financial assets may be impeding the poorer households' ability to generate more environmental income. Females in particular are excluded from fishing activities and are involved mainly in fish trading.

As inequality and inequitable outcomes can pose risks to the sustained success of CBNRM, the Sikunga management committee have different options to achieve more equitable outcomes. Rather than more complicated centralised measures to re-distribute environmental income once it has been generated, which may in itself not be desirable, the conservancy can address the human, physical and financial

[2] Average price per kilo for natural resources: Fish N$20/kg, Firewood$5/kg, Thatching Grass N$0.5/kg.

constraints that poorer households face in gaining the opportunity to generate environmental income. For example, it might consider supporting women's cooperatives to provide vulnerable members of the community with the capital required as has proven successful in other conservancies (Mulonga and Murphy, 2003; Murphy and Suich, 2004). Such programmes may also help overcome the lack of the necessary physical assets required to harvest natural resources (Angelsen et al., 2014; Angelsen and Wunder, 2003; Babulo et al., 2008; Faße and Grote, 2014; Purvis, 2002; Torpey-Saboe et al., 2015).

The conservancy may also wish to include environmental income within its equitable distribution plans, as this would make clear the importance of the resource both in terms of achieving equitable outcomes, but also recognise its importance in contributing to hunting and tourism income.

Any attempts to enhance environmental income opportunities for the vulnerable households, however, would need to consider sustainable yields to ensure that fish stocks remain healthy into the future, which is not currently the case3. Sikunga would therefore need to find an improved approach to the collective management of its natural resources, such as more clearly defined rules with enforcement (Röttgers, 2016), to deliver more equitable and environmentally sustainable outcomes.

Increasing environmental income for the poorest households is, however, a short-term solution. Longer-term CBNRM can work as a bridge to economic development and an increase in off-farm work whilst also protecting the environmental capital of the community and thus sustaining environmental income sources into the future. As seen in Table 5, households from the Asset and Cash Rich cluster have a significantly higher number of household members with a university education.

2.8 Summary and Conclusion

Although conservancies in Namibia have been praised as a successful example of CBNRM implementation, we find mixed results. Our analysis highlights the important role that environmental income plays in reducing inequality within the conservancy at an aggregate community level yet finds conflicting results at the household level.

Our analysis shows that environmental income is an integral part of households' livelihood strategies, particularly for those households holding higher levels of savings, assets and livestock. Thus, whilst

[3] Accurate current estimates of sustainable yields from fish stock remain difficult to calculate in the Zambezi river system, due to rapid decline in populations and high variability in production rates (Tweddle et al., 2015). However, catch data and information on comparable areas in the Zambezi region indicate sustainable yields for the area of between 60,000 and 80,000 kg per year (Downing and Plante, 1993; Turpie, 1999; Tweddle et al., 2015). The proportion harvested by Natural Resource and Agricultural households in Sikunga exceeds this amount.

environmental income improves income equality overall, the poorest households gain little from environmental income within the conservancy.

Furthermore, our analysis highlights the importance of considering the distribution of environmental income within a conservancy and within CBNRM more broadly. Many conservancies currently lack the funding to cover their basic operating costs, and additional funding is needed to ensure the long-term stability of the conservancies. A greater focus on the values and flow of environmental income, the value of which is double that obtained by hunting and other benefits (NACSO, 2014), may help create new revenue or income streams for conservancies. Furthermore, social unrest may escalate as conservancy members grow frustrated at what they perceive to be inadequate financial benefits distributed in a vague and inconsistent manner from year to year (Mosimane and Silva, 2015). Thus, institutions allowing for a clearer and more equitable distribution of environmental income may be important to the long-term sustainability of conservancies.

Our results provide a small insight into the role of environmental income across livelihood strategies in a single conservancy in Namibia. Further research, however, is required on the dynamic impacts that environmental income may have. A qualitative analysis that more wholly incorporates the political economy, structures, institutions and processes within the conservancy as well as the quantitative outcomes would be of significant value. Further, a greater understanding of how environmental income can stimulate rural development highlights the need for environmental income to be incorporated into economy-wide quantitative models, such as regional computational equilibrium models.

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Appendix

Table 7: Description of variables used in Cluster Analysis

Variable	Definition	Justification
Purchased inputs for crop activities	Labour hired to prepare, plant, harvest, and process crops. Cost of seeds, fertiliser and pesticides.	(Nielsen et al., 2013)
Purchased inputs for livestock activities	Labour hired to care for livestock Cost of food and medicine for livestock.	(Nielsen et al., 2013)
Hours allocated to self-employment	Total hours per year dedicated to work on their own business, such as construction, craft or food and catering businesses.	(Nielsen et al., 2013)
Hours allocated to agriculture work	Total hours per year dedicated to work in agriculture, either on the family farm or in paid employment	(Nielsen et al., 2013)
Hours allocated to collecting natural resources	Total hours per year dedicated to collecting and harvesting natural resources. This includes harvesting thatching grass and river reeds, collecting firewood and fishing.	Own consideration
Hours allocated to off-farm, non-agricultural wage work	Total hours per year dedicated to work away from the family farm that is not related to agriculture; for example, as Teacher, Police officer, Military member, Accommodation worker.	(Nielsen et al., 2013) / (Jansen et al., 2006)
Transfers from government, NGOs, family and friends	Cash receipts from people who do not reside in the household. This includes social welfare from government as well as family transfers.	(Nielsen et al., 2013)

Source: Sikunga Survey 2012; own calculations.

3 Assessing Natural Resource Management Through Integrated Environmental and Social-economic Accounting: The Case of a Namibian Conservancy

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Abstract

Local Natural Resource Management (NRM) in its diverse manifestations holds core to its principles that the marginal and vulnerable households are empowered to manage valuable natural resources to improve social and economic equality and conserve biodiversity. Yet studies aiming to identify the impacts often show inconsistent results. Through constructing an integrated Environmental and Social Accounting Matrix (ESAM) we aim to assess how natural resources are used in different sectors, by different livelihoods, and thus delivering different direct and indirect benefits to the community. The study was conducted in Namibia's Sikunga Conservancy, which manages wildlife and fish resources in the Zambezi region. Our village-level ESAM shows an economic structure that strongly disadvantages remote households, and identifies a small sector of the economy that benefits significantly from the use of natural resources. The ESAM approach is able to isolate undesirable socio-economic developments such as unequal benefit sharing, which hinders community development.

3.1 Introduction

Local natural resource management (NRM) concepts, namely community based natural resource management (CBNRM) and comparable programmes such as fisheries co-management and community based fisheries management (CBFM) continue to gather momentum as national decentralisation and democratisation programmes sweep across sub-Saharan Africa (Blaikie, 2006; Dressler et al., 2010, Fabricius et al. 2013, Sowman & Wynberg, 2014). By transferring property rights for natural resources, CBNRM aims to provide communities with an increased incentive to sustainably manage the natural resources they depend upon and at the same time deliver equitable economic growth (Berkes, 2004; Jones & Weaver, 2008)[1].

Despite the popularity of the philosophy, the overall impact of CBNRM remains unclear (Lewins et al 2014; Silva & Mosimane, 2012; Riehl, Zerriffi & Naidoo, 2015). Impacts can be measured at multiple scales; at the national-level, CBNRM programmes appear to be having a positive impact throughout sub-Saharan Africa. Increases in wildlife headcounts (Roe, Nelson, & Sandbrook, 2009) and income (Frost & Bond, 2008; Naidoo et al., 2016) have been recorded in sub-Saharan countries with CBNRM. CBNRM programmes have also been found to boost economic activity in other sectors (Muchapondwa & Stage, 2013). Social Accounting Matrices (SAM) have been applied in Namibia to analyse the impact of hunting tourism (Samuelsson & Stage, 2007) and angling tourism (Kirchner & Stage, 2005), as well as the value of Namibia's protected areas (Turpie et al., 2010), with all studies showing CBNRM helps stimulate growth in other sectors within the Namibian economy. However, benefits at national and community-level may not necessarily trickle down to individual households (Riehl et al. 2015; Nunan, 2006; Leisher et al., 2016).

Using various quasi-experimental methods, recent studies reveal inconclusive results. The impact of CBNRM on income has been statistically insignificant for the average household (Pailler, Naidoo, Burgess, Freeman, & Fisher, 2015; Riehl, 2014; Suich, 2013), whereas improvements in health (Naidoo & Johnson, 2013; Riehl, 2014) and food security (Pailler et al., 2015) have been identified. The question therefore remains, why are the impacts of CBNRM inconsistent?

One possible reason is that particular livelihoods benefit more than others from CBNRM (Suich 2013; Collomb et al., 2008; Scanlon & Kull, 2009). Looking primarily at the direct income and financial aspects while neglecting the indirect benefits from conservation may present another reason why impacts of natural resource management are conflicting (TEEB, 2012; WAVES, 2016). It is well established that the value of natural resources within CBNRM areas far exceeds the economic output from production and tourism (Turpie, Barnes, Lange, & Martin, 2010). Despite the economic value of natural resources, Humavindu and Stage (2015) identified the risk of long-term environmental sustainability due to unsustainable financing of conservancies, particularly younger conservancies, which may fail to generate revenue to cover operating expenditure of their conservation activities. In addition to waning donor funding, the challenge of sustainable financing may partly be explained by the fact that management committees use funds differently. As Mulonga & Murphy (2003) highlight, the increased cash flows from CBNRM activities can be used for multiple purposes, shared directly across households, or invested in community funds or infrastructure. In turn, we have seen that some sectors within CBNRM are complementary, for instance hunting and tourism (Naidoo et al., 2016), whilst others namely livestock and agriculture are often the source of conflict with wildlife-focused sectors (Hoare, 2015; Kahler & Gore, 2015; Mosimane, McCool, Brown, & Ingrebretson, 2014).

As a way to enhance the discussion by analysing how economic, financial and natural resources are distributed within a nature-dependent economy, we constructed an integrated, environmental social-economic accounting matrix (ESAM). The ESAM integrates economic, financial, and natural resources into a single matrix. By incorporating the different sectors, we can observe the linkages between single activities and derive the context specific, direct and indirect income effects of CBNRM in our study region. Analysing the flow of resources between actors and sectors is essentially answering "who does what with whom, in exchange for what, by what means, for what purpose, with what change in the stock" (United Nations, 2009:16), and is key to understanding how the economy causes different outcomes for different social groups.

By showing the linkages between resources and household, we answer the following questions:

- What is the economic contribution of environment and non-environment based activities to the village economy?
- What are the structural linkages between environmental and non-environmental activities in the village economy?
- How is environmental income distributed across livelihoods and regions within the village economy?

We aim to demonstrate the potential of using an ESAM to show the distribution of natural resources and their benefits within a CBNRM environment. More generally, we have constructed a multi-sectoral social accounting matrix at the village level, including additional environmental accounts for selected natural resources. The ESAM provides a consistent data framework that can flexibly be extended and used as a point of reference for economic modelling. Our ESAM complements the few in existence from Faße, Winter, & Grote, (2014), Shiferaw & Holden (2000) and (San Martin & Holden (2004). We however go further and integrate multiple environmental resources within the single ESAM. The rest of the paper is set out with a brief overview of the data for the ESAM, a detailed description of the model, and lastly the results, discussion and conclusion.

3.2 Study Area and Data

3.2.1 Study Area

To demonstrate the usefulness of an ESAM in explaining the impacts of NRM, we selected a conservancy in the Zambezi region of Namibia. The study was part of the SASSCAL (see www.sasscal.org) research portfolio on climate change and adaptive land use, and took place in Sikunga Conservancy, a developing conservancy gazetted in 2009 and hosting wildlife as well as valuable freshwater fish resources. The Zambezi region has a high GINI coefficient and high levels of poverty (National Statistics Agency, 2012). Though rich in biodiversity, regional environmental issues such as overfishing, deforestation, slash-and-burn farming, and poaching continue to grow (Mendelsohn, 2006; Tweddle et al., 2015). The region is also home to the Kavango-Zambezi (KAZA) Transfrontier Conservation Area (TFCA) and supports a number of vulnerable wildlife (NNF, 2013), but also causes serious human-wildlife conflicts (Metcalfe & Kepe, 2008). Fish stocks, located yearlong in the Zambezi river and across the flood plains during the flood season are suffering from overfishing and a lack of coordinated management with cross border Zambia (Abbott et al., 2007; Tweddle et al., 2015). Grazing plains in the Zambezi region, which support large numbers of livestock, are slowly being eroded. Deforestation, increasing livestock headcounts and slash-and-burn farming have contributed to the erosion and degradation of floodplains in the region (Purvis, 2002). Agriculture practices are rudimentary and are based on low-input/low-output farming, placing greater pressure on denuded land (Pricope et al., 2015). Forest resources in the area are generally undervalued and undermanaged, with few controls placed on timber and firewood collection. Other natural resources such as thatching grass and river reeds are controlled by fixed-period licences (Barnes, MacGregor, Nhuleipo, & Muteyauli, 2010).

Economically, off-farm job opportunities in the area are limited, and the majority of households tend to eke out maize-based subsistence existences supported by natural resource extraction (Kanapaux & Child, 2011). Cash income in the region is mostly earned through a handful of high-paying tourism or government jobs in the regional capital, Katima Mulilo, with a high number of households also depending on social welfare payments such as pensions and orphan payments (Suich, 2010).

Sikunga is rich in natural resources with grassland floodplains and Mopane woodlands covering the 287km² area (Mendelsohn, 2010). The conservancy consists of six main villages clustered in three locations. As can be seen in (Figure 1), three villages are located close to the main road into Sikunga. Sandwiched between the only road in and out of the conservancy and the Zambezi River, Kalimbeza, Kena, and Nasisangani have the greatest access to transport to the regional capital. Sifuha, the largest of all villages, and Kalundu are a five kilometre walk across the floodplains to the main road. The third region consists of Malindi, an isolated village that can only be reached via an 18km journey by foot or by bike across the sandy plains. The three sub-areas (*main road*, *semi-isolated*, and *isolated*) are able to access different natural resources to varying extents.

Like many conservancies, Sikunga earns the majority of its income from the sale of hunting licences, however there are also two Lodges within the area which support the highly lucrative angling tourism sector. The Lodgeshave formal benefit sharing arrangements with the conservancy, and in this way Sikunga is unique as it earns income from hunting as well as angling. As tourism in the conservancy is heavily focused on the unique angling in the area, the dwindling fish stocks (Tweddle et al., 2015) are putting the lucrative tourism income, as well as the livelihoods of the poorest and most vulnerable, at risk. In 2012, Sikunga established a pilot Fish Protected Area (FPA) and a fishery management plan, which, if successful, may prove a model for future freshwater FPAs (Tweddle, 2012).

3.2.2 Data

The ESAM is primarily built from household survey data collected from within the conservancy. There were approximately 440 households in Sikunga in 2012, and we sampled 200 (45%). The sample was random, based on household lists provided by the conservancy. As the sampling was non-stratified, results reflect the full population of Sikunga. Targeting the household head, the survey covered all economic activities, including the collection, consumption, and trade of all natural resources. Agricultural inputs and outputs were also recorded. For all transactions, the agent, origin and destination of goods produced or traded were recorded. For all fish and timber data, species were recorded so as to better develop growth functions and measure changes in natural capital. Secondary data sources were used to complete information gaps from the primary data. This information was used to calculate environmental stocks and growth rates[2].

3.3 Method

The SAM method was originally envisaged to observe national accounts in an input-output table to better inform policy development (Taylor & Adelman, 1996). Acknowledging both the impact and dependence on natural resources, the accounting framework was expanded to include the physical or financial values of natural resources (United Nations, 2003).

The ESAM is a specification of the System of Environmental and Economic Accounting (SEEA), continuously advanced to include better coverage of Ecosystem Accounting (UNSTAT, 2016). It plays an important role in policy planning, and is critically needed as a monitoring and planning tool at the regional and village level (Angelsen et al., 2014; Shiferaw, Freeman, & Swinton, 2005; de Anguita & Wagner, 2010).

3.4 The Environmentally Extended Sikunga Village SAM

The ESAM (Table 8) represents the total transactions within the Sikunga economy for a single year; it contains the links between economic activities and changes in environmental stocks. Activity columns and rows reflect different production processes that produce services and goods (commodities). Inputs, such as land, labour, and livestock are included in Factor accounts. Institutions - encompassing households, government and businesses - are the consumers of the goods and services produced or imported. Commodities produced, yet not consumed in the year, are considered increases in capital, as are changes in savings, and are recorded in the capital accounts. Imports and exports, as well as financial transfers from outside the conservancy, are accounted for in the rest of the village/Namibia/world accounts. For all accounts, entries in the columns represent payments made, with corresponding entries in rows reflecting payments received. To explore the extent to which natural resources are being used to develop sustainable and equitable economic growth, we hold production activities, commodities, factors of production, capital accounts and households as endogenous. Exogenous accounts are government and rest of Namibia/world. It should be noted that 'A' represents the endogenous accounts, 'L' are leakage values outside the conservancy economy, and 'X' are exogenous injections from outside Sikunga (Agaje, 2008).

Prices have been based on market prices where possible (United Nations, 2014). In the case of forests and fish stocks, the value of the resources produced during 2012 are based on 2012 market prices. The value of future income generated from growth and regeneration, recreational and non-consumptive use is excluded. The prices of natural resources used in the production of other goods, for instance trees used for the production of firewood, are based on a partitioning of the cost of labour and the end-price of the produced good. This approach is similar to the partitioning of operating surpluses between natural and produced assets as outlined in the SEEA 2003[3] (UN et al., 2003). All values in the table are reported in Namibian Dollars (NAD$) where NAD$1.00 is roughly PPP$0.60

Table 8: Overview of ESAM Framework

		Endogenous Accounts											Exogenous Accounts		
		Activities				Commodities		Factors		Institutions	Savings		Rest of Village / World		
		Activities – On-farm	Activities-Off-farm	Natural Resource Extraction	Natural Resource Growth	Commodities (Agricultural and non-agricultural)	Commodities – Natural Resources	Factors	Factors – Natural Resources	Institutions and Conservancy	Capital – Savings and Commodities	Capital – Natural	Government	Rest of Village	Rest of World
Endogenous	Activities – On-farm					$A_{1/5}$				$A_{1/9}$					
	Activities-Off-farm					$A_{2/5}$									
	Natural Resource Extraction					$A_{3/5}$				$A_{3/9}$					
	Natural Resource Growth						$A_{4/6}$								
	Commodities (Agricultural and non-agricultural)	$A_{5/1}$	$A_{5/2}$							$A_{5/9}$	$A_{5/10}$			$X_{5/13}$	$X_{5/14}$
	Commodities – Natural Resources			$A_{6/3}$								$A_{6/11}$			
	Factors	$A_{7/1}$	$A_{7/2}$	$A_{7/3}$	$A_{7/4}$										$A_{7/14}$
	Factors – Natural Resources			$A_{8/3}$	$A_{8/4}$										
	Institutions and Conservancy							$A_{9/7}$	$A_{9/8}$		$A_{9/10}$		$X_{9/12}$	$X_{9/13}$	$X_{9/14}$
	Capital – Savings and Commodities									$A_{10/9}$			$X_{10/12}$		
	Capital – Natural			$A_{11/1}$						$A_{11/9}$			$X_{11/12}$		
Exogenous	Government							$L_{12/7}$	$L_{12/8}$			$L_{12/11}$			
	Rest of Village					$L_{13/5}$		$L_{13/7}$		$L_{13/9}$	$L_{13/10}$				
	Rest of World					$L_{14/5}$		14/7		$L_{14/9}$	$L_{14/10}$				

Source: adapted from de Anguita & Wagner (2010) and Adelman, Taylor, & Vogel (1988)

3.4.1 Activities

We separate the activities into four groups; agriculture, off-farm, natural resource growth, and natural resource extraction activities. Agriculture activities focus mainly on maize and livestock and commercial rice farming. Off-farm activities consist mainly of government and tourism services. Natural resource growth and extraction activities are included for each individual resource. Ecosystem services, such as cultural services have been excluded from the current version of the ESAM. Only natural resources that are economically or environmentally significant to the economy have been included (UN et al., 2003). Our approach to the recording of environmental transactions is based on the SEEA 2012 framework, and on the representation of livestock developed by Gelan, Engida, Caria, & Karugia (2012) for their Ethiopia SAM. The growth of timber and increases in fish biomass creates the commodities "timber" and "wild fish", which are recorded in the sub matrix $A_{4/6}$. The commodities can then be used as inputs for other production activities such as "firewood harvesting" or "fishing". Commodities can also be taken from or contribute to existing stock levels. This is discussed further below.

Natural resource extraction activities represent the production of goods based on the extraction of natural resources, such as fishing, firewood harvesting etc. Goods produced from natural resources which are sold are included in sub matrix $A_{3/5}$, and those which are consumed directly by the household are recorded in $A_{3/9}$. Slash-and-burn farming produces agricultural assets, in the form of farming and grazing land, and is initially recorded as a production of the commodity "farm land" in $A_{3/5}$, before being recorded as an increase in investment recorded in $A_{5/10}$. However, this practice comes at a large environmental cost, which is initially recorded in the value of trees lost in $A_{3/5}$ and is eventually absorbed by the conservancy in $A_{5/9}$.

As with natural resource extraction, agricultural and non-agricultural goods produced and sold by households in Sikunga are recorded in $A_{1/5}$, while the goods they produced and consumed at home are recorded in $A_{1/9}$. Cell $A_{1/5}$ includes the output from the commercial rice farm run by a government owned business within the conservancy.

3.4.2 Commodities

Similar to the structure of activities, commodities are separated into agricultural, non-agricultural goods and services, and natural resource commodities. Commodities used as inputs for other production activities are recorded in $A_{5/1}$ and $A_{5/2}$, with environmental commodities, such as trees and wild fish, recorded in $A_{6/3}$. Commodities purchased by households, regardless if they were produced inside or outside Sikunga, are recorded in $A_{5/9}$. Where commodities were reported as being sold within Sikunga, yet not able to be assigned to a particular institution, these values were recorded in a 'Rest of Village' account in sub matrix $X_{5/13}$. Sub matrix $X_{5/14}$ also records the value of commodities exported to Namibia and the rest of the world.

Where the value of natural commodities used as inputs is less than the value of the sustainable yield, an increase in natural capital is recorded in $A_{6/11}$. Similarly increases in storages of crops or livestock headcounts are recorded in $A_{5/10}$ as an increase in agricultural capital. Thus the ESAM is able to directly report the sustainable use of different natural resources in different activities.

3.4.3 Factors

The Value Added matrix consists of cells $A_{7/1}$, $A_{7/2}$, $A_{7/3}$ and $A_{7/4}$, for labour and agricultural factors, and $A_{8/3}$ and $A_{8/4}$ for natural resource factors. Where residents of the community were employed outside the boundary of the village, this is reported in $A_{7/14}$. The value for labour, where possible, was based on income reported for different activities. For on-farm activities, labour values were calculated based on reported time-use.

The distribution of payments to multiple factors for single activities is driven by payments for labour. This approach is consistent with the SEEA Central Framework 2012[3]. Capital rents are recorded for livestock and land in cells $A_{7/1}$, $A_{7/2}$, and $A_{7/3}$ along with Labour. Capital rents for environmental assets are recorded in $A_{8/3}$ and $A_{8/4.}$ As with physical capital, capital rents on environmental resources can only be calculated when there is no consumption of existing capital (i.e. the use of natural resources is sustainable (United Nations, 2014)).

3.4.4 Institutions

Institutions consist of the government, conservancy management, tourism operators, and households. Factor payments made to households from agricultural capital and labour are recorded in $A_{9/7}$, with factor income from natural resources recorded in $A_{9/8}$. This includes the net income from environmental rents for the conservancy as the conservancy controls the environmental resources of Sikunga. Income from government pensions or other welfare is recorded in $X_{9/12}$.

Where net savings are reported by households and other institutions, these are recorded in $A_{10/9}$. However, where net losses for agricultural and financial capital are noted by households, these are put in $A_{9/10}$. Households within Sikunga also sent money to households outside of the conservancy and these transactions are recorded in $X_{9/13}$ and $X_{9/14}$. Transfers flowing in the opposite direction are put in $L_{13/9}$ and $L_{14/9}$.

We group the households by both their livelihood strategy and their geographic location. We include geographic location considering that research on CBNRM has shown the important role of geographic capital in determining access to natural resources (Blaikie, 2006; Kanapaux & Child, 2011). There are four unique livelihood strategies, which we identified using a two-step cluster analysis[5]. The four groups are: *diversified low-input low-output rural workers; natural resource and agricultural workers; skilled off-farm worker; asset and cash rich households.* The four groups are then further sub-divided in the ESAM based on their geographic location: *main road*; *semi-isolated*; *isolated*. A summary of the assets and resource use of these groups is provided in Table 9.

Table 9: Income sources for the Livelihood Strategies in Sikunga

	Cluster 1 *(diversified low-input low-output rural workers)*	**Cluster 2** *(natural resource and agricultural workers)*	**Cluster 3** *(skilled off-farm workers)*	**Cluster 4** *(asset and cash rich)*
Number of Households	97	49	29	24
	Annual Household Expenditure (NAD$)			
Expenditure on Consumption Goods	$ 7,706 [b,c,d]	$ 9,874 [d]	$ 11,552 [d]	$ 17,446
	Natural Resources			
Net Income Fish % Sold	$ 877 [b] (35%)	$ 11,184 [c,d] (77%)	$ 120 [b] (32%)	$ 2071 (64%)
Net Income Firewood % Sold	$ 2,408 [b,c] (0.4%)	$ 3,876 (1.4%)	$ 1,819 (0.9%)	$ 1,943 (0%)
Area Slash-and-burned (HA)	2.1	3.3	2.6	3.7
	Other Income			
Agriculture	$2,026 [b,d]	$3,929	$3,097	$5,131
Wage and Casual income	$6,499 [c]	$12,174 [c]	$24,929 [d]	$29,568
Welfare and Remittances	$3,216 [c,d]	$3,144 [c,d]	$1,578 [d]	$11,538
	Total Income (NAD$)			
Total Income	$15,026 [b,c,d]	$34,307	$31,543	$50,251

b,c,d indicate the mean is statistically different at alpha = 0.10. b indicates significantly different to cluster 2, c significantly different to cluster 3, and d significantly different to cluster 4. All continuous variables were tested with the Mann-Whitney U-test. Source: Sikunga Survey Data, 2012; own analysis.

Cluster 1 households, the largest of the four groups in terms of total households (48%), have the lowest annual income ($15,026) of which forestry resources make up 16% of their total income. This group consumes over 3,100 kg of firewood per household per year, however tend not to exploit fish resources.

Cluster 2 households consists of 49 households (25% of the sample) and generates most of its income from natural resources, as well as unskilled employment in agriculture sector. Households in this group catch on average around 860 kg of fish per household per year, which accounts for over 30% of the household's income. They also extract the highest amounts of firewood of all livelihood strategies.

Cluster 3 households have the second highest level of expenditure in the conservancy. Their higher expenditure is fuelled by comparatively high wage incomes from stable government jobs, mostly in military, police, or government departments in Katima Mulilo. This cluster represents around 15% of households in the community.

Cluster 4 households, consists of 24 households, around 12% of the conservancy, and achieve the highest levels of expenditure through high-paying, private pensions as well as salaries from younger family members still residing in the household. Despite their wealth, households in this group are the second highest users of fish resources and cleared the second highest amounts of land through slash-and-burn farming.

3.4.5 Capital

The capital accounts are used to record changes in natural, physical and financial resources. Where the consumption of commodities is greater than those produced and imported, there must be a decrease in stocks. This decrease in stock, referred to as consumption of existing capital, is recorded as an input to the production activity (United Nations, 2014). In cell $A_{11/1}$ we report the consumption of existing natural capital. This occurs when consumption levels of wild fish are above sustainable yield levels. Increases in agricultural capital are distributed amongst the households in $A_{10/9}$. Increases in natural capital are also assigned to the conservancy in $A_{11/9}$, while increases in land from slash-and-burn farming are recorded for households in $A_{10/9}$. The financial capital account contained in $A_{10/9}$ and $X_{10/12}$ is used as a balancing account, and reports the net difference between incomes and expenditures for institutions, government and the conservancy (Round, 2003; United Nations, 2014).

3.4.6 Government and Conservancy

As the government and conservancy institutions have been considered exogenous for the multiplier analysis, they must be separated from the other institutions. However, the accounts are similar to other institutional accounts, such as earning factor income from land via the rice farm in $L_{12/7}$ or environmental rents in $L_{12/8}$.

3.4.7 Rest of the Village, Rest of Namibia, Rest of World

The Rest of the Village account is used to account for the flow of goods, services, and capital which are traded without a clearly defined producer or consumer. For example, a household may have reported that it produced 100kg of maize and sold it within Sikunga, however, we are unable to determine which family, or which household cluster they sold it to. In order to include these transactions, we therefore include it in $X_{5/12}$. Other imports from outside Sikunga are recorded in $L_{14/5}$. There is a relatively small amount of hired labour in Sikunga, with the majority of labour for livestock herding imported from across the border in Zambia. Factor costs for imported labour are recorded in $L_{13/7}$ and $L_{14/7}$.

3.5 Multiplier Analysis

The economic linkages between environmental resources and their users have been analysed by using constrained multiplier analysis, although most published SAMs apply unconstrained multipliers. Unconstrained multipliers are generally more simplified, assuming that factors and capital are unlimited and accessible at constant costs (Breisinger, Thomas, & Thurlow, 2010). In the context of an ESAM, this is rather idealistic and too removed from reality. For example, in our study area fish resources are being used unsustainably, and fish reproduction rates cannot be ramped up or down depending on short-term demand.

To better account for this we conduct a series of constrained multiplier analysis and place a limit on different environment sectors and resources. These constraints are also important in more accurately measuring the multiplier effects as unconstrained multipliers can often overestimate demand linkages (Breisinger et al., 2010; Round, 2003).

The unconstrained multiplier is derived as follows. We firstly define which accounts are considered endogenous, and which are considered exogenous (Breisinger and Ecker, 2006). These are shown in Table 10. We then derive submatrix A_n, which contains the expenditure coefficients created by dividing each cell by its column total (Lewis and Thorbecke, 1992; Taylor and Adelman, 1996). A_n only contains the expenditure coefficients of endogenous accounts. Assuming that A_n can be inverted, then the multiplier matrix A_n, minus the identity matrix I is inverted to give the multiplier matrix.

$$M = (I - A_n)^{-1} \quad (1)$$

A vector matrix of X, consisting of exeogenous changes, can then be multiplied by M, to observe the changes in endogenous accounts Y.

$$Y = (I - A_n)^{-1} X \quad (2)$$

$$Y = M \cdot X \quad (3)$$

Multiplier Matrix M is broader than the Leontief multiplier, as changes in expenditure are reflected through production activities and household incomes (Faße et al., 2014). The matrix M is based on the average expenditure propensities, rather than the marginal propensities and provides us with the unconstrained multipliers4. However, in order to derive the constrained multipliers, we must further classify endogenous accounts as 'Constrained' or 'Unconstrained'. In our analysis we constrain accounts differently based on a number of scenarios, but conceptually, the constrained matrix structure is based on equation 1. We define the constrained multiplier as being (Resosudarmo and Thorbecke, 1996):

$$M_c = \begin{bmatrix} (I - C_u) & 0 \\ -R & -I \end{bmatrix}^{-1} \cdot \begin{bmatrix} I & Q \\ -R & -(I - C_c) \end{bmatrix} \tag{4}$$

Where C_u is the marginal expenditure propensities matrix of unconstrained accounts, and C_c the marginal expenditure propensities matrix of constrained accounts. R is the marginal expenditure propensities matrix of unconstrained accounts on constrained accounts and Q is the marginal expenditure propensities matrix of constrained accounts on unconstrained accounts. This matrix model reflects changes in unconstrained exogenous sectors and constrained endogenous sectors on unconstrained income and constrained exogenous accounts (Hartono and Resosudarmo, 2008) .

Similar to equation 3 we can then incorporate the constrained multiplier matrix in.equation 4 to model the impact of exogenous changes on endogenous income accounts to give us equation 5 (Sassi, 2010). However, the changes can be modelled in a number of ways. We can model an increase in exogenous demand for unconstrained sectors (X_u), or an increase in exogenous supply of constrained sectors (Y_c) (Lewis and Thorbecke, 1992).

$$\begin{bmatrix} Y_u \\ X_c \end{bmatrix} = \begin{bmatrix} (I - C_u & 0 \\ -R & -I \end{bmatrix}^{-1} \cdot \begin{bmatrix} I & Q \\ -R & -(I - C_c) \end{bmatrix} \begin{bmatrix} X_u \\ Y_c \end{bmatrix} \tag{5}$$

Table 10 ESAM with Constrained and Unconstrained accounts

		Endogenous Accounts			
		Constrained Accounts	Unconstrained Accounts	Combined Exogenous Accounts	Row Total
Endogenous Accounts	Constrained Accounts	Acc	Acu	Xc	Yc
	Unconstrained Accounts	Auc	Auu	Xu	Yu
Combined Exogenous Accounts		Lc	Lu	F	W
Row Total		Yc	Yu	T	

Source: Agaje (2008)

3.6 Results

3.6.1 The Economic Contribution of Environment and Non-environment-based Activities to the Village Economy

The village ESAM presented in Table 11 shows aggregated household clusters across the different regions, as well as disaggregated environment accounts. GDP, excluding environmental accounts, was around NAD\$ 3,890,000 ($A_{13/1}$:$A_{14/2}$) in 2012 or NAD\$ 4,215 per capita. This figure is below the GDP per capita of NAD\$ 6,709 for the Zambezi region (National Statistics Agency, 2012), and reflects the exclusion of income from jobs located outside the case study's production boundary. The GDP from environmental accounts is worth more than NAD\$ 22,000,000 ($A_{13/3}$:$A_{15/4}$) driven by the value of forest growth within the conservancy area.

The village economy is relatively closed with few leakages. The production value of NAD\$ 4,197,000, excluding environmental accounts, means that GDP is approximately 93% of total production. Despite 75% of households producing maize, Sikunga remains a net importer. Of the roughly 84,000 kg maize consumed annually in Sikunga, 83% is imported from the regional capital. Livestock still holds a prominent place in the culture and economy of Sikunga and accounts for around 14% (NAD\$ 585,000 - $A_{1/6}$) of non-environmental production. However, expanding livestock and maize farming are responsible for the destructive consumption of forest resources; slash-and-burn farming and land clearing currently destroys about a third of the value of annual growth in forest stocks. The analysis revealed that fish resources were harvested at unsustainable rates. As can be seen in Table 11, the natural capital consumed, here the value of unsustainable fish extraction (NAD$66,928 - $A_{23/3}$), is around 17% of the total valued growth in fish stocks (NAD$375,546 – $A_{3/7}$).

The ESAM shows that the contribution of environment-based activities is central to the village economy, more specifically, that the output of natural resource extraction and harvesting is almost double that of both agriculture and off-farm activities. Yet the distribution and utilisation of natural resources appears geared towards particular institutions and groups. This can be seen across agriculture, off-farm and natural resource extraction activities.

Table 11: Aggregate Village Extended Environmental Social Accounting Matrix of Sikunga

		Activities				Commodities								Factors		
		1. Activities – On-farm	2. Off-farm Activities	3. Natural Resource Extraction	4. Natural Resource Generation	5. Crops	6. Livestock	7. Fish	8. Trees	9. Harvested Natural Commodities	10. Government Services	11. Tourism + Conservation Services	12. Other Goods and services	13. Labour Factors	14. Agricultural Factors	15. Environment Factors
Activities	1. Activities – On-farm	-	-	-	-	2,012,783	585,547			-			-			
	2. Off-farm Activities	-	-	-	-					-	328,921	422,440	631,330			
	3. Natural Resource Extraction	-	-	-	-	-				8,259,977			-			
	4. Natural Resource Generation	-	-	-	-	-		375,546	21,647,625				-			
Commodities	5. Crops	49,184	4,800													
	6. Livestock															
	7. Fish			375,546												
	8. Trees			7,857,369												
	9. Harvested Natural Commodities			92,498												
	10. Government Services	-	-		-	-				-						
	11. Tourism + Conservation Services															
	12. Other Goods and services	-	252,587	-	-	-				-			-			
Factors	13. Labour Factors	1,146,763	1,116,824	553,188	-	-				-			-			
	14. Agricultural Factors	1,618,103	8,480	-	-	-				-			-			
	15. Environment Factors	-	-	4,817	22,023,171	-				-			-			
Institutions	16. Main Road Households	-	-	-	-	-				-			-	2,502,530	220,248	145,891
	17. Semi-isolated Households	-	-	-	-	-				-			-	808,439	107,320	70,262
	18. Isolated Households	-	-	-	-	-				-			-	151,936	- 14,526	29,818
	19. Conservancy Management													-	8,479	21,782,017
	20. Government														1,305,062	
	21. Others	-	-	-	-	-				-			-			
Savings	22. Agriculture Capital	-	-	-	-	-				-			-	-	-	-
	23. Natural Capital	-	-	66,928	-	-				-			-	-	-	-
	24. Savings	-	-	-	-	-				-			-	-	-	-
Rest of Village / World	25. Rest of Main Road Households	-	-	-	-	2,760	30,270			31,149	460		58,898	-	-	-
	26. Rest of Semi-isolated Households	-	-	-	-	2,268	1,130			9,230	2,170		29,244	-	-	-
	27. Rest of Isolated Households	-	-	-	-	-	410			3,880	930		7,716	-	-	-
	28. Rest of Sikunga Households	-	-	-	-	2,832	33,830			51,557	30,920		44,344	8,406	-	-
	29. Outside Sikunga	-	-	-	-	454,142	26,596			11,510	54,395		1,384,782	91,260	-	-

Table 12: Aggregate Village Extended Environmental Social Accounting Matrix of Sikunga (continued)

		Institutions						Savings			Rest of Village/World						TOTAL
		16. Main Road Households	17. Semi-isolated Households	18. Isolated Households	19. Conservancy Management	20. Government	21. Others	22. Agriculture Capital	23. Natural Capital	24. Savings	25. Rest of Main Road HHs	26. Rest of Semi-isolated HHs	27. Rest of Isolated Households	28. Rest of Sikunga	29. Outside Sikunga	30. Outside Namibia	
Activities	1. Activities – On-farm	123,503	83,477	8,740		-	-	-	-		-	-	-	-	-	-	2,814,050
	2. Off-farm Activities	-	-	-			-	-	-		-	-	-	-	-	-	1,382,691
	3. Natural Resource Extraction	406,032	192,816	91,521				-	-		-	-	-	-	-	-	8,950,346
	4. Natural Resource Generation	-	-	-			-	-	-		-	-	-	-	-	-	22,023,171
Commodities	5. Crops	302,300	136,139	35,441				14,060			500	600	300	900	1,934,881		2,479,105
	6. Livestock	67,026	23,810	1,400				399,003			18,933	39,938	-	37,241	90,222	210	677,781
	7. Fish																375,546
	8. Trees								13,790,256								21,647,625
	9. Harvested Natural Commodities	62,944	22,130	5,854	7,489,755			126,460			52,670	75,126	1,960	69,863	306,527	63,556	8,369,343
	10. Government Services	73,320	12,673	2,882		328,921	-	-									417,796
	11. Tourism + Conservation Services	4,535	3,335	610	129,670		268,890								15,400		422,440
	12. Other Goods and services	825,120	357,812	92,865			111,280	-	-		348,106	85,440	1,800	34,944	41,600	8,160	2,159,714
Factors	13. Labour Factors	-	-	-			-	-	-		-	-	-	-	861,630	-	3,678,405
	14. Agricultural Factors	-	-	-			-	-	-		-	-	-	-	-	-	1,626,583
	15. Environment Factors	-	-	-			-	-	-		-	-	-	-	-	-	22,027,988
Institutions	16. Main Road Households	-	-	-		296,600	23,400	-	-		1,000	-	-		188,680	-	3,378,349
	17. Semi-isolated Households	-	-	-		114,000	-	-	-		-		-	900	55,530	-	1,156,451
	18. Isolated Households	-	-	-		48,200	36,000	-	-		-	-	-	-	24,500	-	275,928
	19. Conservancy Management								66,928								21,857,424
	20. Government																1,305,062
	21. Others	12,036	7,351	2,828			-	-			-	-	-	-	-	-	22,215
Savings	22. Agriculture Capital	413,751	123,503	2,269			-	-	-		-	-	-	-	-	-	539,523
	23. Natural Capital				13,790,256			-	-		-	-	-	-	-	-	13,857,184
	24. Savings	1,032,793	155,770	31,518	447,743	517,341	-417,355	-	-		-	-	-	-	-	-	1,767,810
Rest of Village / World	25. Rest of Main Road Households	700	-	-			-	-	-	296,972	-	-	-	-	-	-	421,209
	26. Rest of Semi-isolated Households	-	-	-			-	-	-	157,062	-	-	-	-	-	-	201,104
	27. Rest of Isolated Households	-	-	-			-	-	-	-8,876	-	-	-	-	-	-	4,060
	28. Rest of Sikunga Households	2,500	630	-			-	-	-	-31,171	-	-	-	-	-	-	143,848
	29. Outside Sikunga	51,790	36,405	-			-	-	-	1,408,090	-	-	-	-	-	-	3,518,970
	30. Outside Namibia	-	600	-			-			-54,268							71,926

Source: Sikunga Survey Data 2012; own analysis

3.6.2 Structural Linkages Between Environmental and Non-environment-based Activities

To explore the structural links between environment and non-environment-based activities we look at the multiplier analysis in Table 13. Through analysing the linkages with other sectors, it can be seen how natural resource-driven growth may develop the economy, and whether growth in non-natural resource sectors could at the same time lead to indirect negative impacts on the natural capital in the region. In terms of linkages between environmental and non-environmental sectors we generally find a one-way relationship. Maize and livestock farming, two historically significant sectors, have weak linkages with extractive activities. An exogenous increase in demand for one unit of Maize or Livestock would lead to an increase in natural resource extraction of 0.03 and 0.05 units (Table 13). Off-farm activities also indicate low linkages with extractive sectors - as increases in tourism, conservation and commercial services have few knock-on effects on natural resources - with output multipliers for natural resources all below 0.17 units (Table 13). In contrast, environmental extractive activities are strongly linked with each other. An exogenous increase in demand for 1 unit of thatching grass and river reeds would lead to an overall increase in 1.38 units for the village economy (Table 13).

Livestock is one of the traditional livelihoods indicating a positive impact on GDP and total income. An increase in exogenous demand for one unit of livestock would increase GDP by 1.02 units and income by 0.77 units. However, for each increase in livestock demand, there is an expansion in 0.22 units of land use through enhanced factor demand (Table 13).

The GDP and income multiplier for fish is low, as the sector is constrained and any increase in exogenous demand must be supplied via an increase in imports. The fishery sector has a doubly important role to play in the economy, contributing as much to GDP directly through catching and processing as it does indirectly by attracting tourists for the tourism sector (Table 13).

In looking at the services industry within Sikunga, analysis revealed that tourism and conservation services have the largest impact on GDP. An increase in exogenous demand for tourism and conservation would result in increases in GDP by 1.25 and 1.23 units respectively. As production for these two sectors occurs largely within the conservancy, the model concludes that growth in GDP translates into corresponding aggregate income growth. Another positive sign for the potential of tourism and conservation services is that the two sectors have very weak links with natural resource extraction. This is highlighted by increases in output of 1.48 and 1.40 units, with only 9% of the growth is due to enhanced natural resource extraction.

Table 13: Constrained Multiplier Analysis – Livestock, Slash-and-burn, Fish and Timber Sectors Constrained

	Maize	Livestock	Fish	Firewood	Thatching Grass + River Reeds	Trade and Self Employment	Tourism	Conserva-tion	Commerc-ial	Gov't
Factors										
Unskilled Labour	0.16	0.70	0.30	0.40	1.05	0.68	0.84	0.65	0.27	0.35
Skilled Labour	0.00	0.02	0.01	0.02	0.03	0.14	0.38	0.49	0.11	0.60
Land & Seeds	0.13	0.22	0.01	0.01	0.03	0.02	0.03	0.09	0.01	0.02
Livestock	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Resources	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
GDP Multiplier	0.29	1.02	0.32	0.43	1.17	0.84	1.25	1.23	0.39	0.97
Geographic										
Main Road HHs	0.12	0.56	0.21	0.28	0.71	0.55	0.84	0.80	0.26	0.69
Semi-isolated HHs	0.04	0.21	0.07	0.09	0.23	0.18	0.27	0.26	0.08	0.22
Isolated HHs	0.01	0.00	0.02	0.03	0.07	0.05	0.06	0.05	0.02	0.03
Livelihood Strategies										
Diversified Low-input Low-output Rural Workers	0.05	0.27	0.10	0.13	0.33	0.23	0.31	0.27	0.10	0.19
Natural Resource and Agricultural Workers	0.05	0.22	0.08	0.10	0.27	0.19	0.26	0.22	0.08	0.15
Skilled Off-farm Workers	0.05	0.21	0.09	0.13	0.32	0.30	0.53	0.56	0.16	0.56
Asset and Cash Rich	0.02	0.07	0.03	0.03	0.09	0.06	0.08	0.06	0.02	0.04
Total Income Multiplier	0.17	0.77	0.30	0.40	1.02	0.78	1.17	1.11	0.36	0.94
Total Output Multiplier	0.33	1.05	1.02	0.76	1.33	1.48	1.40	1.36	0.44	1.08
Own Sector Multiplier	0.24	0.89	0.64	0.51	0.40	1.28	1.00	1.00	0.31	0.80
Linkages with other sectors	0.09	0.16	0.37	0.24	0.94	0.20	0.40	0.33	0.12	0.28
Linkages with Natural Extraction	0.03	0.05	0.92	0.56	1.09	0.13	0.17	0.15	0.05	0.12

Source: Sikunga Survey Data 2014; own analysis

3.6.3 The distribution of environmental income across livelihoods and regions

The previous section identified which sectors may support sustainable growth and which sectors may escalate environmental degradation. In order to observe the extent to which the structure of the economy will lead to equitable economic growth, we look at the multiplier analysis through normalised income multipliers (Table 14). Income multipliers are normalised for each of the three regions and four livelihood strategies by the weighted average for value added (Arndt, Garcia, Tarp, & Thurlow, 2012) and by population. We include the population-based weighted average as value added weights may partially reflect existing inequality.

The normalised multipliers show that *main road households* tend to gain between 1.3 and 1.4 times the weighted average induced income. Households in this region gain well above the weighted average for all activities, indicating the structural imbalance in the economy. Conversely, the *isolated region* with its lack of infrastructure and limited access to markets suffer significantly when gaining from any induced income development.

The normalised multipliers for the fish and firewood sectors provide conflicting impressions as the sectors appear to support households that are either extremely poor, or extremely well-off. We find that fish resources provide households from the poorest livelihood strategy (*diversified low-input low-output rural workers*) with 1.19 times the weighted average (value added) for fish while, *skilled off-farm workers* gain double that average income. Results are similar for fish and firewood using the population weighted average. Reflecting the *main road households*' access to the river and flood plains, these households benefit 2.8 times more from fish generated income than the weighted average (value added), indicating the highest income disparity across all normalised measures and all sectors.

The story is slightly more positive when looking at the normalised indicators for the different livelihoods strategies. Initially, *asset and cash rich* households appear to suffer a disadvantage within the village economy, however the low normalised multipliers are slightly misleading. The vast majority of income for this cluster is generated by income from outside the conservancy; either from high-return pensions, or salaries outside Sikunga. In consequence, any increase in induced demand within the village economy is unlikely to have any impact on their production, and thus income generating activities.

The poorest group of households, *diversified low-input low-output rural workers*, benefit from induced demand for commodities produced from unskilled activities such as maize and livestock farming, as well as natural resource extraction. This partly reflects that their production and consumption activities are driven within the village. On the other hand, households in this cluster gain little from conservation and tourism activities. Increases from conservation employment or tourism are likely to flow through to the wealthy and well educated *skilled off-farm workers*.

Table 14: Normalised Income Constrained Multipliers

	Maize	Livestock	Fish	Firewood	Thatching Grass + River Reeds	Trade and Self Employment	Tourism	Conserva-tion	Commerc-ial	Gov't
Normalised by Value Add										
Geographic										
Main Road HHs	1.43	1.31	2.80	1.38	1.32	1.12	1.16	1.17	1.27	1.10
Semi-isolated HHs	0.47	0.50	0.90	0.45	0.43	0.36	0.37	0.38	0.41	0.35
Isolated HHs	0.15	0.01	0.29	0.14	0.14	0.10	0.08	0.07	0.09	0.04
Livelihood Strategies										
Diversified Low-input Low-output Rural Workers	1.15	1.41	1.19	1.13	1.12	1.05	1.15	0.59	0.78	0.36
Natural Resource and Agricultural Workers	0.99	1.15	0.97	0.93	0.92	0.86	0.94	0.49	0.64	0.30
Skilled Off-farm Workers	1.07	1.07	1.16	1.16	1.07	1.37	1.96	1.23	1.28	1.08
Asset and Cash Rich	0.41	0.38	0.32	0.31	0.30	0.27	0.28	0.14	0.19	0.07
Normalised by Population										
Geographic										
Main Road HHs	1.41	1.40	1.42	1.42	1.42	1.42	1.42	1.43	1.42	1.43
Semi-isolated HHs	0.47	0.53	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Isolated HHs	0.15	0.01	0.14	0.14	0.15	0.12	0.10	0.09	0.11	0.06
Livelihood Strategies										
Diversified Low-input Low-output Rural Workers	1.16	1.24	1.18	1.18	1.19	1.13	1.06	1.00	1.07	0.89
Natural Resource and Agricultural Workers	1.00	1.00	0.97	0.96	0.98	0.92	0.87	0.83	0.88	0.73
Skilled Off-farm Workers	1.08	0.94	1.20	1.20	1.14	1.47	1.80	2.09	1.75	2.66
Asset and Cash Rich	0.42	0.33	0.32	0.32	0.31	0.29	0.26	0.24	0.26	0.18

Source: Sikunga Survey Data 2012; own analysis.

3.7 Discussion

CBNRM is a local governance institution that aims deliver locally adapted sustainable and equitable rural development (Dressler et al., 2010, Fabricius et al., 2013; Sowman & Wyberg, 2014). Our ESAM analysis shows that benefit-sharing matters. This is in line with recent research done by Mosimane and Silva (2015) who found that local governance institutions in Namibian conservancies have not yet developed fair, transparent and accountable benefit-sharing systems facilitating participation. In a behavioural field experiment related to our ESAM analysis, Roettgers (2016) revealed the significance of institutions favouring cooperation, specifically pro-social norms, leadership and communication.

The structural linkages between environmental and non-environmental activities identified in our study area indicate that the natural resource based sectors within the CBNRM economy are strongly interconnected, while non-natural resource based sectors appear to be growing separately and somewhat disconnected. The ESAM analysis shows that the current structure of Sikunga's economy is neither sustainable nor equitable. Natural capital is being consumed at unsustainable rates with minimal consideration over the long-term economic and ecological consequences and may lead to regime shifts with damaging economic and environmental impacts.

However, Sikunga is an emerging conservancy with high potential for diversifying the nature-based tourism sector due to its rich aquatic and terrestrial biodiversity. Being part of a broader network that includes also transboundary natural resource management (TBNRM) approaches (Abbott et al., 2007), the process of community development depends on external factors, local management strategies (Fabricius et al., 2013:273), and the collaboration between traditional leadership, government and external stakeholders (Mawere, Mabeza & Shava, 2014). As pointed out by Barendse et al. (2016), one limiting external factor is the government's inadequate implementation capacity, so that local governance institutions have narrow capacity to develop natural resource stewardship. This holds for wildlife as well as for fishery management (Ngwira, Kolawole & Mbaiwa, 2013; Nunan 2006; Nkhata, Breen & Abacar, 2009; Lewins et al., 2014; Sutton, Murray & Rudd, 2014; Cox, Wilson & Pavlovich, 2016).

The ESAM tool has highlighted negative developments, associated with investments by the Sikunga Conservancy Management which appear to advantage established elites and wealthy households, and those located near the main infrastructure. In particular, the isolated village of Malindi has no clear economic development opportunities based on the current structure of Sikunga's economy. More concerning, however, is that income multipliers indicate conservancy-based economic activities such as tourism and conservation jobs are skewed to be pro-rich rather than pro-poor, findings similar to that of Elliot & Sumba (2011) who recommend the launch of transparent benefit-sharing agreements.

Geographical clustering shows the opportunity to reconsider land management and zooning in favour of remote villages. We also show that biased income allocation in favour of asset-rich households causes an unsustainable increase in demand for cattle and grazing land, explained by the cultural high value local people still attribute to owning cattle. As the Zambezi region is already at maximum carrying capacity

(Mendelsohn, 2006, 2010, Pricope et al., 2015) any increase in farming land will be due to land-use change. As deforestation intensifies, the growth rate of forest stocks will decrease, which in turn may escalate pressure on households due to loss of fuel sources, shade, protection from desertification and other ecosystem services.

Value-added sectors such as community based tourism may increase capital rents on the natural resources without putting at risk natural capital stock levels (van der Duim, Lamers & van Wijk, 2015). 'Conservation tourism' as promoted by the African Wildlife Foundation is one promising example for market-based conservation that might be an option for Sikunga (van Wijk et al., 2014).

3.8 Conclusion

This article contributes to existing research in several ways. It is an addition to the limited number of village-level SAM and ESAMs, and provides a valuable insight into the economic and environmental linkages within a CBNRM context. By including sub-villages within the ESAM, our model highlights the importance of geographic capital, particularly in the context of a region undergoing rural-urban change. Finally, the model also challenges the cultural importance of particular livelihood activities, and their future role in the livelihood strategies of rural households in north-eastern Namibia.

The result indicates that the CBNRM program in Sikunga so far has done little to enhance sustainable and equitable development; rather the transfer of property rights to the conservancy has allowed the elite and wealthy households to extract greater rents on the natural resources, and put at risk the natural capital. The lack of incentives for the vulnerable *isolated* households to protect the wildlife plains that surround them could eventually jeopardise the wildlife and the hunting-based income that the governing committee members have grown to depend on.

To enhance economic development, the Conservancy Management Committee may consider prioritising conservancy employment opportunities for disadvantaged households such as stewards for the wildlife plains or other similar activities.

Methodologically, the assumptions behind the multiplier analysis place some limitations on our conclusions, and suggest that future research considers not only the greater use of village-level ESAMs across a wider number of study areas, but their use as an input into more village-level computable equilibrium and agent based models. Furthermore, ESAMs are only able to incorporate the flows and changes in stocks of natural resources and services. While concentrated flows of goods and services may indicate particular power balances within a community, they are insufficient to explain why different groups may be marginalised, and the broader political ecology. Secondly the quantification of both the volume and value of ecosystem services is a key input into ESAMs, and there are many natural resources and ecosystem services, particularly cultural services, which though difficult are worth quantifying and valuing in this context.

The Sikunga Conservancy is unique in many ways. Firstly, while the majority of the income for the conservancy management committee is obtained from the sale of hunting licences, like most conservancies, however its current tourism income is fishing, and not wildlife based. Secondly, it is also a comparatively young conservancy, which means that historical and cultural factors may influence the results reported within the CBNRM context.

Our results make a valuable contribution to the debate methodologically, and with a wider application may enhance the distribution of direct and indirect benefits within the CBNRM context.

Notes

1. In the literature the term CBNRM is often used in the broader context of natural resources management or management of the commons, including wildlife, fish, forest and water resources, involving some degree of co-management between the government and communities (Turner 2004; Roe et al. 2009). In our paper we apply this broader definition of CBNRM.

2. Secondary sources used to calculate fish growth rates were (Hay et al., 2002) and (Downing & Plante, 1993). Secondary source used to calculate tree growth were (Barnes et al., 2010; Kamwi, 2003; Laamanen, Otsub, & Tubalele, 2002).

3. See page 51 of the SEEA 2003 for more detail.

4. For more information see section *V Asset Accounts*, page 153 (United Nations, 2014).

5. Two-step cluster analysis is an objective way to group the households into groups with common mixes of livelihood strategies using both categorical and continuous variables. It is preferred to hierarchical techniques due to its ability to integrate categorical and continuous variables and its ability to group clusters based on the objective AIC and BIC indicators (Mooi & Sarstedt, 2011) . Cluster analysis is commonly used in Livelihood Strategy Analysis. For more information regarding the use of cluster analysis in identifying livelihood strategies see (Brown, Stephens, Ouma, Murithi, & Barrett, 2006).

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4 The Effect of Risk on Cooperation and Effort: A Lab-in-the-field Experiment

This chapter is a version of

Morton H., Grote U., Winter E., "The Effect of risk on co-operation and effort: A lab-in-the-field experiment"

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Abstract

Households in rural areas of developing countries are often thought to gain through greater cooperation with one another. Public goods can provide the basis for economic growth, yet investments to maintain public goods can often deliver little or no return. Community infrastructure may be washed away in monsoonal rains or lost in wildfires. It is therefore possible that the risk of investing time, money and energy to cooperate for little or no benefit may threaten the sustained cooperation that public goods, and many vulnerable households, depend on. To better understand the impacts of risks on cooperation we construct a novel lab-in-the-field public good game which incorporates risks and is based on real effort tasks. We use a within-subject approach to measure the impact of risk, and a between-subject approach to measure the impact of communication treatments, resulting in a mixed experiment design. We find that when risk is present, individuals significantly decrease their contribution to the public good, as well as decrease their total effort exerted in each round. Furthermore, we also find that external treatments such as communication and observation, which are effective in enhancing cooperation in risk neutral settings, are ineffective in the presence of risk. Our design demonstrates that the decrease in cooperation in the presence of risk is not simply due to risk aversion, but the impact of risk on other-regarding preferences. This challenges the stylised facts which are often assumed to enhance cooperation and may have ramifications for the design of community development projects.

4.1 Introduction

Development agencies and economists frequently highlight the role that collective action and cooperation can play in insuring rural households against shocks as well as driving economic growth (Dongier et al., 2003; Durlauf and Fafchamps, 2005; King and Samii, 2014; Thorp et al., 2005; Vollan, 2012; Woolcock, 1998).

Communities can come together in a number of ways to contribute to the provision of public goods, such as to construct or maintain irrigation infrastructure (Speranza et al., 2016), build microgrids (Kirubi et al., 2009) or form agricultural (Meinzen-Dick et al., 2004) or environmental (Renting and Van Der Ploeg, 2001) cooperatives. Yet the success of community driven development and collective action are dependent upon sustained cooperation within an inherently risky environment.

Infrastructure may be damaged or become stranded assets due environmental disasters and extreme weather (Krysanova et al., 2010) and agricultural cooperatives can be hit by droughts, limiting their impact and sustainability (Shiferaw et al., 2008). There is a genuine risk that the time and energy invested in cooperation can deliver no benefit, even when all group members trust and cooperate with each other. How the collective action groups respond to risks greatly influences their resilience and thus long-term sustainability (Borda-Rodriguez et al., 2016). At the heart of Ostrom's (1998) work on cooperation and collective action is the concept that through increased trust and reciprocity, cooperation can deliver a greater net benefit, yet little is known about cooperative behaviour where there is a risk that cooperation will deliver no benefit.

The uncertainty and risk associated with suffering losses from a public good contribution is not the only risky endeavour for rural households in developing countries. The rural poor are also subjected to a myriad of risks to their private enterprises (Dercon, 2005). Pests may consume crops before their harvest, death and disease may rob households of labour and income or livestock may be lost or stolen. Rural households are therefore forced to make decisions between two risky options, a risky investment in their private good or a risky investment into a public good.

The importance of individual decisions under risk has become increasingly prominent in development literature, particularly in Africa, with risk preferences (Liebenehm and Waibel, 2014) and various choices under risk such as insurance (Giné and Yang, 2009) and crop choice (Lybbert et al., 2010) all receiving a greater focus in the literature. The impact of risk on individual decisions is critical to understand, however with more than US$30billion invested globally in community driven development (Wong, 2012), which is dependent upon sustained cooperation of groups (Mansuri and Rao, 2004; Ostrom et al., 2014), there is a need to explore or explain the behaviour and interactions between individuals under the presence of risk (Fafchamps et al., 2013; McCarter et al., 2010; Stoddard, 2017). Further highlighting the need to understand cooperation under risk is that where aid has not had the impact intended in risky environments, it is due to a failure of collective action and cooperation (Ostrom, 2011; Ostrom et al., 2014). We therefore wish to contribute to the need to understand the decision-making of individuals under the presence of risk by exploring the impact of risk on cooperation and cooperative behaviour. It is this context of the provision of public goods in rural areas of developing countries that motivates our research and its contribution.

Set in a rural community in the Zambezi region of north-eastern Namibia we conducted a novel field experiment where individuals participate in two sequential public good games, one without risk, followed by one without risk. Our research objectives were: (i) to understand the impact of risks on an individual's willingness to cooperate; (ii) to understand whether external interventions that have improved cooperation in risk-neutral settings, such as communication, have a similar impact in the presence of risks; and (iii) to understand and isolate the impact that simultaneous risks have on effort exertion levels.

This paper makes several important contributions. In the classic voluntary contribution mechanism, participants decide to allocate a portion of their initial endowment to a public goods account, whilst retaining the rest in their private account. We modify the game by endowing individuals with an amount of time, with which they can utilise to producing goods (tokens) which they can then choose to allocate to the public good account and/or their private account.

To isolate the effect of risk and communication treatments we use a mixed design. Participants complete two sequential linear voluntary contribution mechanism games. For most participants the first game is played without risk, whilst in the second public good game participants face risks associated with their private and public goods. The within-design approach is commonly used when comparing the impact of risk on cooperation (Dickinson, 1998; Wit and Wilke, 1998). Individuals remain in the same group for both games, and any communication treatments, such as *Cheap Talk* and *Observation*, are introduced halfway through game 1 and game 2 and are also the same for both games, and thus forms the component of our between design.

The results from our novel lab-in-the-field public good game in rural Namibia show that when risks are present, individuals decrease the amount of effort they contribute to the public good; they are less cooperative. These results can also be attributed to the impact of risk on other-regarding preferences, and are not influenced by risk-aversion or discontinuous preferences. Furthermore, we also find that the presence of risks negates the effectiveness of external factors such as communication and observation that have consistently been found to facilitate cooperation. In regards to the impact of risk effort on exertion levels, we find that even though the risk scenario is pay-off equivalent, and controlling for fatigue and learning effects, participants respond to risk by decreasing their total effort. We also find that males and older individuals exert less effort on average, with or without the presence of risk.

4.2 Study Area

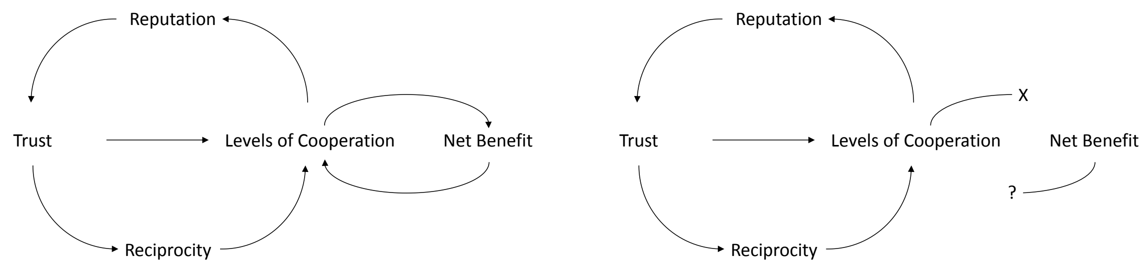
Participants for the experiment were recruited from a remote rural conservancy in the Zambezi region of north-eastern Namibia, approximately 40km from the regional capital Katima Mulilo. The Zambezi region is one of the economically poorest in Namibia, with 41.7% of households below the poverty line and extreme inequality highlighted by a Gini coefficient of 0.59 (National Statistics Agency, 2012). We constructed our lab-in-the-field in six villages[5] within the conservancy, selecting participants randomly from household lists from each village. The occupations and incomes of participants varied from high paying off-farm jobs (government, police/military and tourism), to subsistence livelihoods based on natural resources and agriculture (harvesting firewood, river reed and thatching grass or the dwindling fish stocks). This is reflective of the Zambezi region (Ashley and LaFranchi, 1997; Kanapaux and Child, 2011; Mulonga and Murphy, 2003; Suich, 2010).

4.3 Experiment Design

Reflective of the context of our motivation for this research, the provision of public goods in rural areas of developing countries, the experiment design is based on the linear public good game. Ostrom's (1998) cycle of cooperation (Figure 4) has formed the basis for much of the research on group cooperation. Much of the research in public goods has focused on factors that enhance trust, reputation and reciprocity, such as such as heterogeneity amongst group members, group size, and external treatments such as punishment and communication (Chaudhuri, 2011; Ledyard, 1995). Our experiment design is based to explore how risks associated with and the actual loss of benefits can impact on levels of cooperation, an area that little is known about (Fafchamps et al., 2013; Van Dijk et al., 2004).

[5] The conservancy consists of six main villages grouped into three sub-regions. Figure 1 shows three villages located close to the main road. The largest of the villages Sifuha, and its sister village Kalundu are in the second sub-region. The third sub-region consists of Malindi, an isolated village 18km away from the road, with no form of public or private transport services available.

Figure 4: The cyclical nature of cooperation



Source: Adapted from Ostrom (2010) and Vollan (2012)

4.3.1 Experiment Process

We randomly sampled 215 households from a list of around 440 households registered as living within the conservancy. The sampling was non-stratified, and thus it is representative of the entire conservancy. The artefactual lab-in-the-field experiment was implemented in 43 sessions with each session consisting of one group containing five individuals. Individuals stayed in the same group, and the same treatment for both of the public good games that were played in sequence. In each session the group played two linear public good games, with each of the games consisting of 10 rounds. At the beginning of each session, participants were told they would be taking part in an economic experiment. In order to obtain an unbiased response to risk aversion, we conducted an initial survey regarding the risk-behaviours and preferences of participants. The risk survey questions are strongly correlated with risk preferences (Falk et al., 2013).

4.3.2 Real Effort vs. Chosen Effort in Public Goods Experiments

It is becoming widely accepted that individuals behave differently when they receive money as a windfall gain as opposed to when they make decisions regarding money they have earned (Harrison, 2007; Muehlbacher and Kirchler, 2009). Windfall gains are often valued to a lesser extent, with participants more willing to gamble a windfall gain than their own money (Arkes et al., 1994; Carlsson et al., 2013; Thaler and Johnson, 1990). In the context of public good games, individuals may be more prepared to "gamble" that others will cooperate with money endowed upon them by organisers rather more so than they would be when using their own money. Furthermore, the outcome of a decision becomes increasingly important to an individual depending on the effort invested (Lallement et al., 2014). For these reasons we feel it is important to the experimental design to incorporate an aspect of real-effort.

An additional driving factor behind our inclusion of a real-effort task is that evidence indicates that individuals are willing to invest money and effort in different ways. In some contexts individuals may volunteer their time and effort to a public good, but may be unwilling to part with their earned cash (van

Dijk et al., 2001). In much of rural sub-Saharan Africa, participants have more time than money, thus it is more relevant to observe participants willingness to contribute effort rather than cash (Beard, 2007; Chukwuma, 2016).

The use of real effort in public good games is not completely novel, with several public good games incorporating real effort aspects into their design. Most common are real effort 'hurdle' tasks that players must successfully complete in order to obtain their initial endowment (Cherry et al., 2005). More recently studies have started to incorporate real effort tasks into every round in multi-round games (Carbone and Gazzale, 2011; Filiz-Ozbay and Ozbay, 2014). We build on these multi-round real-effort games, by applying the same real effort task to both the public and the private good. In this way we can be sure that there are no perceived changes in the marginal per capita return for either good once the real-effort task is embedded in the design. In this way we can ensure that our parameters are consistent for all good-types and all players.

4.3.3 Real-Effort Task

Common real-effort tasks used in university laboratories, such as encryption tasks or solving simple equations are unsuitable for lab-in-the-field experiments as they may yield different results due to differing skill sets, rather than differing levels of cooperation. There are several researchers who have led the way in developing and testing real-effort tasks applicable for use with low-educated and or rural poor populations though many of these are unfortunately impractical for repeat-shot games (Beaman and Magruder, 2012) or particularly challenging if not impractical to replicate in the field and our context (Cappelen et al., 2013; Hadnes et al., 2012; Jakiela et al., 2015).

We therefore leverage the principles behind Kemper and Unte (2014) and Barr et al., (2015) who implement repetitive tasks that require no special skill and minimise the potential for learning or specialisation throughout the experiment, such as sorting beans (Kemper and Unte, 2014) or gravel (Barr et al., 2015).

Our real effort task is continuous, played in each round, and is required for contributions to both private and public goods. Our task required players to sort through a series of blank tokens to find a single marked token. The single marked token was placed on a plate with 49 blank tokens. Participants were told they could only turn one token over at a time with one hand and should sort from the top of the plate towards the bottom. This instruction helped to limit learning effects. Players were given two piles of plates, to help them differentiate between the private and the public good. The two piles of plates provided at the start of each round consisted of two different colours, green for the public good and yellow for the private good. Next to each pile of plates were two buckets, again green for the public good and yellow for the private good, where participants could collect the tokens they found during each round. Furthermore, the marked tokens also displayed different pictures for the public and the private good to further help players differentiate between investing effort in the public or the private good.

Figure 5: Marked tokens for the private and public good.

Source: Own design

Players were given two minutes in each round to invest as much effort as possible in searching for tokens. In any given round participants were able allocate their time to searching for tokens to contribute to the private or public good, with no restrictions on switching. It should be noted that at no time did participants run out of tasks to complete within a given round.

4.3.4 Field Setting

Similar to the approach from Kemper and Unte (2014), we sat players in a circle with players looking outwards, to help make each individual's decision private. At each position in the circle, players were seated on chairs, and the plates were placed on a table. Each table had dividers around the edge to further protect the privacy of each player's decision (see Figure 6). However in general, players appeared more focused on investing effort into their task at hand, rather than informing themselves on the decisions of others. During each round, music was played, which included time warnings every 10 seconds, to ensure that the level of effort from participants couldn't be heard. The song played was the same for all rounds. By ensuring that the effort levels of each individual were not known by others we were able to partially control for observed heterogeneity in effort. In between games, the participants were given small refreshments due to the hot conditions, and the effort required to sort through tokens.

Figure 6: Field Setting

Source: Own photo

4.3.5 Social dilemma - Without and With risk

In keeping with the relevant literature, we use a within-subject approach to measure the impact of risk (Gangadharan and Nemes, 2009), and a between-subject approach to measure the impact of communication treatments. Prior to explaining the treatments, we first define the parameters for our public good games with and without risk.

Following the notation of Gangadharan and Nemes (2009), the dilemma our participants faced is as follows. We define the expected payoff for each player in our risk-neutral game as:

$$E(u_i) = \alpha_c x_i + \frac{\beta_c \sum_{i=1}^{n} g_i}{n} \quad (1)$$

which participants aim to maximize given their time-budget constraint and that contributions to the public good cannot be less than zero. Where x_i is the private account contribution, g_i the public good contribution and β_c the certain efficiency of the public good account, and α_c the certain return for the private good. The social dilemma can then be defined when:

$$0 < \frac{g\beta_c}{n} < \alpha_c < \beta_c. \quad (2)$$

In the second game, where participants are then faced with idiosyncratic and covariate risks, the nature of the social dilemma remains the same, but is expressed in the following. First the expected payoff in the public good game with risk is expressed as:

$$E(u_i) = (0.7\alpha_{u1}x_i + 0.3\alpha_{u2}x_i) + (\frac{0.7\beta_{u1}\sum_{i=1}^{n} g_i}{n} + \frac{0.3\beta_{u2}\sum_{i=1}^{n} g_i}{n})\ ) \qquad (3)$$

where $\alpha_{u1}$is the return for the private good when no loss is suffered, and α_{u2} is the return for the private good when a loss is suffered by participant i and $0.5\alpha_{u1}$= α_{u2}. Similarly $\beta_{u1}$is the efficiency for the public good when no loss occurs, and $\beta_{u2}$is the efficiency coefficient for the public good when the group suffers a loss. Again $0.5\beta_{u1} = \beta_{u2}$.

The social dilemma in the risk game can then be expressed as:

$$0 < \frac{g(0.7\beta_{u1}+0.3\beta_{u2})}{n} < (0.7\alpha_{u1} + 0.3\alpha_{u2}) < (0.7\beta_{u1} + 0.3\beta_{u2}). \qquad (4)$$

Finally, to ensure that the size of incentives for the risk and risk neutral game remained the same:

$$(0.7\alpha_{u1} + 0.3\alpha_{u2}) = \alpha_c \qquad (5)$$

$$(0.7\beta_{u1} + 0.3\beta_{u2}) = \beta_c \qquad (6)$$

The parameters for the games with and without risk have been summarised in Table 15.

Table 15: Parameters for the public good games. Note: Values are in Namibian $, and N$1 ~PPP$0.60

			Public Good Game – without risk	Public Good Game – with risk
	α_c	The certain return for each private good token with no risk	2.5	
	β_c	the certain efficiency of the public good with no risk	5	
No loss incurred	-	the probability of receiving α_{u1} for each token contributed to the private good		0.7
	-	the probability of receiving β_{u1} for each token contributed to the public good		0.7
	α_{u1}	the return for each private good token if individual does not suffer idiosyncratic shock affecting their private good		2.94
	β_{u1}	the efficiency of the public good if the group does not experience a covariate shock affecting the public good		5.88
Loss incurred	-	the probability of experiencing an idiosyncratic shock and receiving α_{u2} for each token contributed to the private good		0.3
	-	the probability of the group experiencing a covariate shock receiving β_{u2} for each token contributed to the public good		0.3
	α_{u2}	the return for each private good token if an individual suffers an idiosyncratic shock affecting their private good		1.47
	β_{u1}	the efficiency of the public good if the group suffers a covariate shock affecting the public good		2.94
Expected Utility	α_{eu}	the expected return for each private good token given the probability an individual suffers an idiosyncratic shock affecting their private good	2.5	2.5
	β_{eu}	the expected return for the public good given the probability the group suffers a covariate shock affecting the public good	5	5

Source: Own design

4.4 Treatments

We constructed seven different treatment groups, with each treatment group consisting of two sequential public good games. Participants remained in the same playing group and the same treatment group for the duration of their participation in the experiment. A summary of the treatments and group sizes can be found in Table 16.

4.4.1 Baseline - Effort

In order to control for potential learning or fatigue effects, we establish the Baseline-Effort treatment group. The public good game without risk was played by all participants as game 1. In this game, participants played for 10 rounds. Each round lasted two minutes. Within the two minutes, individuals were able to complete as many real-effort tasks as possible. As mentioned previously, participants were able to choose to invest their effort in searching for tokens for the private, or the public good, and were able to switch their effort allocations within and between rounds. At the end of each round, the number of tokens individuals found for the private and or the public good were recorded on each individual's playing sheet. The amount of tokens contributed by group members to the public good was then recorded and written on each individual's playing sheet by the enumerator. Individuals then used the calculator to calculate the dollar value of the tokens they collected, and the tokens contributed by other group members. At no time during the game were individuals allowed to communicate with one another. After 10 rounds, the playing sheets were collected, and participants where then given the playing sheet for game 2. In the Baseline – Effort treatment, game 2 was the same as game 1; the public good game with real-effort and no risk. As the games were financially incentivised, one round from game 1 and one round from game 2 were randomly selected to be paid out. At the end of completing both games 1 and 2, an individual selected a card from a shuffled deck of playing cards, to determine which round from game 1 would be randomly paid out. A separate individual then selected another card from another set of playing cards to determine which round from game 2 would be randomly paid out. The average amount players earned was around 1.5 times the average daily salary for the community.

The risk neutral game allows us to identify social preferences of individuals and other benchmarks (Brennan et al., 2008). We use these to control for changes in effort and contribution in the public good game with risk, as will be described in the method section.

4.4.2 Baseline – Risk

This treatment group enables us to observe the impact that the external treatments have in the presence of risk. This group played the public good game without risk, as described in the Baseline – Effort treatment, in game 1. However, in game 2, participants in this group then played a second public good game with real effort which included the presence of risk.

In the second game, participants were simultaneously faced with an idiosyncratic risk to their private goods account and a covariate risk to the group's public goods account. The individual idiosyncratic risk was a 30% chance of losing half of their private good tokens (effectively reducing the value for each token allocated to the private account by 50%). The covariate risk that confronted the group was a 30% probability of losing half the tokens contributed to the public good account (effectively reducing the efficiency of each token contributed to the public good account by 50%).

The shocks were implemented in the following way. At the end of each round, the group was presented with a bag containing 10 marbles; 7 black and 3 white. At first, one participant was selected[6] to pick one marble out of the bag for the whole group. This represented the covariate shock. If a black marble was drawn, no public goods were lost, however if a white marble was chosen, the group lost half of the

[6] This person followed the sequence of the player numbers i.e. it started with Player 1 and moved sequentially to the next player in the circle for the next round

public good tokens. Once the covariate risk had been implemented for the round, each player then took their turn selecting a marble from the bag to see whether they lost half of the tokens they had contributed to their private good account. The marble was replaced in the bag after each player had their turn in facing their idiosyncratic risk. Players were shown the marbles in the bag again before they were mixed and drawn. Whilst the results of the covariate shock were public knowledge to the group, the results of the idiosyncratic shocks were kept private.

In order to ensure that any changes in effort or decisions were not due to a lower expected pay-off, the parameters for the public good game with risk were adjusted to ensure that game 1 and game 2 were pay-off equivalent. As in the Baseline – Effort, one round from both game 1 and 2 were randomly selected to be paid out at the end.

There were no communication treatments for this group.

4.4.3 Communication

It is widely accepted that communication increases cooperation, or more specifically contributions to the public good (Ledyard, 1995). However, whilst this has been proven in different contexts and with different mediums (Chaudhuri, 2011), it has yet to be tested in the presence of risk. As is both culturally relevant and practical in the context of lab-in-the-field experiments, we implement the communication treatment at the end of the fifth round. Prior to the start of round six, participants were able to discuss the effort they as a group should invest in the public good, and reach non-binding agreements. This treatment was implemented after round 5 in both the game without risk (game 1) and the game with risk (game 2). This treatment group is similar to group Baseline-Risk, with the exception that communication is introduced after round 5 in both games.

4.4.4 Observation

As Duffy and Feltovich (2002) first ask in the context of public goods, do actions speak louder than words? The question is becoming increasingly popular, with a number of researchers in the context of public goods focusing on the impact from observing others (Andreoni and Petrie, 2004) or being observed (Filiz-Ozbay and Ozbay, 2014). In rural Africa, it is highly likely that neighbours or community members are able to observe the contributions of others to the public good; and therefore it is necessary to include the impact of being observed by others on an individual's willingness to cooperate. Whilst in the reality of rural community life, the identity of who contributes what would likely be known, in this case, in order to protect the social bonds within the community and reduce potential negative effects following our experiment, we implement Andreoni and Petrie's (2004) 'information' treatment. At the start of round six, participants are informed that at the end of the round the contribution to the public good will be drawn on a piece of paper and shown to the rest of the group. The numbers will be written in a random order on the page and therefore each individual's contribution will remain anonymous. This treatment group is similar to Baseline-Risk, with the exception that observation is introduced after round 5 in both games.

4.4.5 Communication and Observation

The most likely scenario within most group settings in a sub-Saharan African context is that groups, communities or networks first come to reach an agreement regarding the level of cooperation expected, and then observe the extent to which others are complying with the agreement. Therefore, we also include a treatment combining both communication and observation. This treatment group is similar to Baseline-Risk, with the exception that communication and observation is introduced after round 5 in both games.

Table 16: Summary of treatments

Treatment Group		Game 1	Game 2
Baseline – Effort	5 Groups, 25 Participants	No Risk	No Risk
Baseline – Risk	7 Groups, 35 Participants	No Risk	Risk
Communication	11 Groups, 55 Participants	No Risk	Risk
Observation	10 Groups, 50 Participants	No Risk	Risk
Communication and Observation	10 Groups, 50 Participants	No Risk	Risk

Source: Own design

4.5 Econometric Method

Following the call of Harrison (2007), we analyse the multi-round, multi-game data using panel methods. In order to address our research questions we require two separate models; one to analyse the variation in contributions to the public good, and the other to measure the variation in total effort exerted in both games.

In analysing the percentage of contributions to the public good we also employ a general least squares model with individual random effects (Croson, 2007):

$$Cooperation_{ir} = \beta_0 + \beta_1 K_{ir} + \beta_2 O_{ir} + \beta_3 C_{ir} + \beta_4 OC_{ir} + \rho \boldsymbol{G}_{ir-1} + \delta \boldsymbol{S}_i + \gamma \boldsymbol{Z}_i + \epsilon_{ir} \qquad (7)$$

where K represents whether the Risk treatment was active; O indicates whether the Observation treatment was active, C indicates whether the Communication treatment was active; and OC indicates whether the combined Observation and Communication treatment was active. $\boldsymbol{G}_{ir-1}$ is a vector of time variant variables relating to the decisions and outcomes of previous rounds. $\boldsymbol{S}_i$ is a vector of dummies for the session group of person *i*, and was constant across all rounds. $\boldsymbol{Z}_i$ is a vector of time-invariant individual and household characteristics of individual i. The error term ϵ_{ir} assumes some unobserved correlation between individuals within their randomly assigned group, and thus uses clustered standard errors at the group-level. The time variant and invariant variables we included in our regression model can be found in Table 21. Variables included socio-economic variables such as age, gender, education and income; welfare variables such as food security, livestock and land assets; and behavioural characteristics such as trust and willingness to take risks.

As the total effort invested, measured by the total number of private and public good tokens found in round r, can be considered count data, we apply a Poisson random effects regression model using a maximum likelihood estimate (Cameron and Trivedi, 2005). The equation for models where the total effort is the dependent variable is given by:

$$E(y_{ir}|\alpha_i, \boldsymbol{x}_{ir}) = \exp(\ln(\alpha_i) + \boldsymbol{x}'_{ir}\boldsymbol{\beta}) \tag{8}$$

where y_{ir} is the total effort[7] invested by person i in round r, and $\boldsymbol{x}_{ir}$ the time constant and time varying dependent variables as found in eq. 7 (Cameron and Trivedi, 2010). In models 1, 3, and 5 we are only interested in the total effort exerted. α_i has a normal distribution with a mean of 1 and a variance of η; so as to enable a solution which allowed for the inclusion group clustered standard errors (Cameron and Trivedi, 2005; Vossler, 2013).

Finally, we estimate both models using different sub-samples of the data. When we combine the observations from game 1 and game 2 into a single model, we observe the within-individual variation impact of risk on individuals. However, as there are potential learning and fatigue effects, we also observe the between-individuals variation of risk between individuals, and do this by using a sub-sample consisting only of observations from Game 2.

We also observe the between-individuals variation comparing the results of those with and without communication using sub-samples containing observations from game 1 or game 2.

4.6 Results

Firstly we first present a brief overview of some descriptive statistics of our sample and the main variables of interest in the experiment. Table 17 shows that the households in our sample earn around N$850 per month from agriculture salaries and $560 from non-agriculture salaries. This is below the average income for the region, but excludes income from subsistence farming and natural resources. Our

[7] Total number of tokens invested in the private good plus the total number of tokens invested in the public good

sample consists of younger participants averaging 33 years of age with just under 10 years of education. Despite their time in education however, most participants rate their ability to read and write as below average, and their numerical skills as average. The participants hold around 1.5 hectares of land which they use predominately for crop farming. The 11 cows per household may appear high, but this figure is inflated by some large herds in a smaller number of households. The participants knew members of their group an average of 14 years, which reflects the low migration rate for the area. On average, participants answered five of the eight comprehension questions correctly, which indicates they have initially understood the game relatively well. Average contributions to the public good in game 1 are around 51% yet drop to 42% in game 2, which although appear high, are within the range of other studies. Women exerted more effort overall, but were slightly less cooperative. The higher levels of cooperation are not surprising as the study area is a conservancy in Namibia and its governance structure and philosophy is based on community cooperation (Bandyopadhyay et al., 2009).

Table 17: Descriptive Results of Sample

	Total Sample	Male	Female
Number of Observations	215	73	142
Number of Public Good Tokens (No Risk)	2.93	2.78	3.00 **
Number of Private Good Tokens (No Risk)	2.83	2.40	3.04 ***
Number of Public Good Tokens (With Risk)	2.67 +++	2.32	2.86 ***
Number of Private Good Tokens (With Risk)	3.73 +++	3.43	3.89 ***
Size of Individual Public Good Loss	1.74	1.72	1.75
Size of Individual Private Good Loss	0.52	0..49	0.54
Trust	2.82	2.74	2.86 ***
Willingness to take risks	3.43	3.93	3.17 ***
Food Security	51.44	57.52	48.31 ***
Livestock	11.51	24.73	4.71 ***
Land	1.53	1.77	1.41 ***
Agricultural Income per month (N$)	849.59	1548.48	500.14 ***
Non-agricultural Income per month (N$)	560.79	597.56	545.65
Shock Impact	12.96	12.29	13.30 ***
Age	32.97	30.34	34.32 ***
Education	9.40	10.08	9.06 ***
Comprehension	5.04	5.05	5.04
Familiarity	14.29	14.84	14.00 ***

Note: * = 10% significance level, ** = 5% significance level, *** = 1% significance level in comparing Males with Females. + = 10% significance level, ++ = 5% significance level, +++= 1% significance level in comparing the averages for game 2 with game 1. Two sided t-tests and Mann-Whitney tests were used as appropriate depending on the variable. Source: Sikunga Survey Data, 2014; own analysis.

The following results will highlight the most relevant coefficients from our regressions. For a full output of our regression please see the appendix in Table 22.

4.6.1 The Impact of Risk on Cooperation

Our results to both Model 1 and Model 3 show that the idiosyncratic and covariate risks have a negative impact on the effort invested in public goods. The coefficients for the presence of risk are negative and statistically significant in both models. Model 1 shows that risk decreases contributions to the public good by 7% compared to a risk-neutral payoff equivalent setting. The coefficient includes the behaviour of individuals across games 1 and 2, however, as there is also a potential learning effect, we also utilise between-individual variation by analysing results using only the sub-sample of observations from game 2. When comparing the behaviour of individuals in game 2 who played the public good game without risk, with the behaviour of those individuals who played the public good game with risk in the second game, we find that the risk of idiosyncratic and covariate shocks decreases contributions to the public good by 25% (Model 3).

Table 18: Econometric Results – impact of risk on cooperation

	Games 1 and 2	**Game 2**
	Model 1	**Model 3**
Dependent Variable	Contribution to the public good (Percentage of tokens contributed to Public Good)	Contribution to the public good (Percentage of tokens contributed to Public Good)
Rounds	1-20	11-20
Within or between-individual variation?	Within-individual	Between-individual
Regression	GLS, RE	GLS, RE
Risk	-0.073*	-0.245**
	(-0.041)	(-0.102)
Size of Individual Public Good Loss $_{(t-1)}$	0.002	0.000
(Covariate game shock)	(-0.003)	(-0.003)
Size of Individual Private Good Loss $_{(t-1)}$	-0.011	-0.002
(Idiosyncratic game shock)	(-0.007)	(-0.007)
Rounds since Public Good Loss	0.000	-0.001
	(0.000)	(-0.004)
Constant	0.657***	0.757***
	(-0.154)	(-0.164)
Other Controls?	Yes	Yes
N	4074	1935
Number of Groups	215	215
R-squared - within	0.05	0.01
R-squared – between	0.45	0.38
R-squared – overall	0.21	0.22
sigma_u	0.14	0.17
sigma_e	0.25	0.22
Rho	0.25	0.37

Note: * = 10% significance level, ** = 5% significance level, *** = 1% significance level. Standard errors shown in brackets are clustered at the group-level. Source: Sikunga Survey Data, 2014; own analysis

In previous research, where risk or uncertainty has been associated with either the private or public good, there has been a corresponding decrease (increase) in the good which has (doesn't have) risk or uncertainty associated with it (Cherry et al., 2015; Dannenberg et al., 2014; Gangadharan and Nemes, 2009; Howe et al., 2016; Levati and Morone, 2013; McBride, 2010). The direction of our results is therefore consistent with the previous literature in finding that overall, risk will decrease cooperation.

There are three possible explanations for the decrease in cooperation. It is possible that inequality seeking behaviour may drive the decrease in cooperation, with individuals seeking to isolate themselves from the losses and wins of the collective (Bault et al., 2008) and would be reflective of the high inherent inequality within the region (National Statistics Agency, 2012). However, inequality seeking behaviour has not consistently been found (Dreber et al., 2014; Linde and Sonnemans, 2015), and we have not specifically controlled for it in our design.

It is possible that loss aversion may also be playing a role in the decrease in cooperation. Loss version implies that the impact of a loss is perceived to be worse than the equivalent gain is perceived to be good (Tversky and Kahneman, 1992). Thus although the risk is equal on both the private and public good, the loss/gains in the public good loom larger. Individuals may therefore be seeking to avoid the potential larger losses (and gains) by contributing more to their private good.

Thirdly, it is possible that the decrease in cooperation is due to excuse behaviour (Exley, 2015) where the presence of risk provides a veil with which individuals are able to rationalise their internal selfish motivations (Dana et al., 2004; Haisley and Weber, 2010; Karni et al., 2007; Krawczyk and Le Lec, 2010). This behaviour has been consistently found in two-player games, and this would be the first time it has been shown in a social dilemma.

4.6.2 The Impact of Risk and Shocks on Effort

Despite the public good game with and without risk being payoff equivalent, individuals were not prepared to invest as much effort in the presence of risk, as they were without risk. This can be seen by the negative coefficients for Risk in Model 4, where the presence of risk decreases total effort by 14% (see Table 19). The coefficient for dummy for the presence of risk in Model 2 and Model 4 differs. When comparing within-individual variation by pooling observations from game 1 and game 2, we find that risk has a positive impact on total effort in the pooled sample, however this result is misleading. As the risk variable reflects a dummy for all rounds in game 2, it can also effectively be a dummy for all rounds 11-20. Therefore in the pooled sample it is possible that this dummy variable captures learning effects which led to higher success rates in completing the task in game 2, and thus offsetting the impact of risk.

Therefore, we analyse the results from model 4, which compares the behaviour of groups with risk with groups without risk and controls for learning effects.

Table 19: Econometric Results – impact of risk on effort

	Games 1 and 2	Game 2
	Model 2	**Model 4**
Dependent Variable	Total Effort (Number of Tokens found per round)	Total Effort (Number of Tokens found per round)
Rounds	1-20	11-20
Regression	Within -individual Poisson, RE	Between-individual Poisson, RE
Communication (Game 1)	0.064***	
	(-0.021)	
Observation (Game 1)	0.084**	
	(-0.037)	
Observation & Communication (Game 1)	0.057**	
	(-0.027)	
Communication (Game 2)	0.088**	0.092**
	(-0.036)	(-0.039)
Observation (Game 2)	0.007	0.004
	(-0.019)	(-0.029)
Observation & Communication (Game 2)	-0.045***	-0.018
	(-0.015)	(-0.015)
Risk	0.125***	-0.134***
	(-0.018)	(-0.048)
Constant	2.020***	2.233***
	(-0.144)	(-0.148)
Other Controls?	Yes	Yes
Log(sigma)	-4.19	-4.59
Sigma	0.12	0.10
N	4074	1935
Number of Groups	215.00	215.00
Log likelihood	-8614	-4138

Note: * = 10% significance level, ** = 5% significance level, *** = 1% significance level. Standard errors shown in brackets are clustered at the group-level. Source: Sikunga Survey Data 2014; own analysis.

From prospect theory one may conclude that participants are overweighting the probability of losing, and therefore, decreasing their effort more than the expected payoff may otherwise signal. Limited research on the risk preferences of sub-Saharan African farmers has identified them as having non-linear preferences, with a tendency to overweight small probabilities and underweight large probabilities (Liebenehm and Waibel, 2014). This behaviour is reflective of loss aversion which has often been seen as a possible explanation for low-input/low-output agriculture in sub-Saharan Africa (Binswanger and Rosenzweig, 1986; Holden and Lunduka, 2014; Yesuf and Bluffstone, 2009). Experiments and research monitoring the impact of insurance on effort or input levels have also found that insuring risks increases investment and effort (Hill and Viceisza, 2011; Leblois et al., 2013; Macours, 2013). However, to our knowledge, our experiment is the first that has directly been able to measure the negative impact of risk on effort levels in that in the presence of risk, in a pay-off equivalent situation, individuals will decrease their total effort.

4.6.3 The Impact of External Treatments on Cooperation and Effort With and Without Risk

In Table 20, the coefficients for our treatments in public good games without risk from game 1 (Model 5), show that only Communication and Observation statistically significantly increase the contributions to the public good by 22% on average, consistent with results where risk is not present (Ledyard, 1995). However, the treatments that proved effective in enhancing cooperation in risk-neutral settings are rendered largely ineffective in the presence of risk. For example, in Model 3, in the public good game with risk we find that none of the communication treatments are significant in increasing the contribution to public goods.

Table 20: Econometric Results – influence of treatments on cooperation in the presence of risk

	Games 1 and 2	Game 2	Game 1
	Model 1	Model 3	Model 5
Dependent Variable	Contribution to the public good (Percentage of tokens contributed to Public Good)	Contribution to the public good (Percentage of tokens contributed to Public Good)	Contribution to the public good (Percentage of tokens contributed to Public Good)
Rounds	1-20	11-20	1-10
Within or between-individual variation?	Within & Between	Between	Between
Regression	GLS, RE	GLS, RE	GLS, RE
Communication (Game 1)	0.040		0.065
	(-0.037)		(-0.04)
Observation (Game 1)	-0.017		-0.002
	(-0.034)		(-0.039)
Observation & Communication (Game 1)	0.174***		0.216***
	(-0.06)		(-0.06)
Communication (Game 2)	-0.019	-0.026	
	(-0.038)	(-0.036)	
Observation (Game 2)	0.043	0.040	
	(-0.036)	(-0.032)	
Observation & Communication (Game 2)	0.059	0.034	
	(-0.04)	(-0.024)	
Risk	-0.073*	-0.245**	
	(-0.041)	(-0.102)	
Constant	0.657***	0.757***	0.693***
	(-0.154)	(-0.164)	(-0.146)
Other controls?	Yes	Yes	Yes
N	4074	1935	1935
Number of Groups	215	215	215
R-squared - within	0.05	0.01	0.05
R-squared – between	0.45	0.38	0.57
R-squared – overall	0.21	0.22	0.32
sigma_u	0.14	0.17	0.15
sigma_e	0.25	0.22	0.24
Rho	0.25	0.37	0.29

Note: * = 10% significance level, ** = 5% significance level, *** = 1% significance level. Standard errors shown in brackets are clustered at the group-level. Source: Sikunga Survey Data 2014; own analysis

With regards to the observation treatment, we find it has no impact whether risk is or isn't present, this is consistent with the finds of Andreoni and Petrie (2004) although contradictory to Filiz-Ozbay and Ozbay (2014). We do however find that when observation is combined with communication in risk-neutral settings, it has a greater positive impact on cooperation than communication itself. This is likely to due to the consequential effect of making an agreement, and then observing the extent to which it is being enforced.

There is unfortunately very little literature that can explain why these treatments are rendered ineffective in the presence of risk. Research has found that in ambiguous settings, communication leads more to decisions that are closer to an risk-neutral conclusion (Keck et al., 2014). Burton and Sefton (2004) however found that communication was more effective in low risk situations than high risk, due to the smaller distances in the relevant equilibriums.

One possibility is that the fear of loss creates “noise” which interferes with the messages coming from the rest of the group. We find that other factors such as village characteristics have more of an impact in the presence of risk than communication treatments (Table 22). The stronger impact of these internal individual characteristics and demographics indicates is possible that the presence of risk results in individuals drawing on aspects of their life which they have a deeper understanding of and connection with such as past experience and their community.

Finally, this finding may also reinforce the strength and impact of excuse behaviour identified in the previous section – in that even when communication and observation is present, individuals may still feel justified in utilising the risk to avoid more pro-social and cooperative behaviour.

4.6.4 The Impact of Individual Characteristics on Cooperation and Effort

Our control variables in Table 22 also present some strong statements. We find that our gender variable shows that males exerted around 20% less effort than females, with similar results obtained with or without the presence of risk. These are similar to other real effort experiments in Africa (Kemper and Unte, 2014), and reflect the cultural responsibilities of the woman compared to the obligations of the men. Similarly we find that an increase in age decreases the total effort by 1%, again with or without the presence of risk. In risk neutral settings we find that participants from remote areas, where inequality is lower, contribute 30% more to the public good than participants from villages located closer to the major infrastructure. When risk is present, the higher levels of contribution from participants in remote villages decreases to 12%.

Our control variable, ‘’Comprehension”, had a marginal impact on effort and cooperation levels (<1%, and only at the 10% significance level). Finally, in terms of education, we find that education has no significant influence, which reinforces the value of our real-effort task.

4.7 Conclusion

Research to date has barely covered the issue of cooperation under risk, and how this may in turn impact the long-term benefits of group formation, cooperation and community driven development. In this paper we use a real-effort public good game primarily to investigate the impact of risk on cooperation.

By introducing the presence of idiosyncratic and covariate risks, we conclude that individuals facing a social dilemma with risk in both choices are more likely to defect than in risk neutral settings. These results are supported by findings from two-player games, where the presence of risk enables individuals to justify more selfish behaviours.

The decrease in cooperation in the presence of idiosyncratic and covariate risks is further complicated as external treatments such as communication and observation appear to be ineffective in risky settings. Finally, our real-effort experiment was also able to reinforce the long-held assumption that uninsured risks decrease individuals willingness to exert effort compared to pay-off equivalent risk neutral settings.

There are several policy and empirical conclusions that can be drawn from our study. The most obvious is that future studies focussing on public goods or common pool resources, particularly those dealing with issues in developing countries may need to consider the inclusion of risks in their experiment design. By including risks into the design, they may be able to further enhance the external validity, particularly if the experiment is being used to inform policy decisions.

Despite our study identifying a clear impact of risk on cooperation, we have not been able to determine whether it is social or individual behaviour theories driving the decisions of individuals. Therefore future studies are warranted on two fronts, firstly to replicate these results and confirm the impact of risk on cooperation, and secondly to further isolate the drivers behind the decrease cooperation.

Although one must be careful to use field experiments as the basis of policy interventions (Harrison, 2014), our results raise an important question in the design of development interventions that require cooperation in risky environments. Interventions reliant on cooperation for success may need to consider firstly which mechanisms they use to enhance cooperation. Whilst the number and type of communication treatments we implemented were limited, these proved ineffective and other forms, such as punishment or enforceable agreements may also prove less effective than practitioners may expect. An alternative approach to enhancing cooperation however may be to neutralise the risk, at least the risk posed to the public good, or cooperative output via some form of insurance mechanism (Barnett et al., 2008). Whilst our study did not address the transaction costs of purchasing insurance for a private or public good, it did show the negative impact of risk on effort, thus neutralising risk by some form or another may help sustain cooperation in risky environments.

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Appendices

Appendix 1: Variables used in regressions

Table 21: List of variables used in the regressions

Variable	Definition
Communication	A binary variable set to 1 when communication was allowed prior to the beginning of the round.
Observation	A binary variable set to 1 when the group was informed at the start of the round that at the conclusion of that round, the contributions would be anonymously shown to the group.
Communication and Observation	A binary variable set to 1 when communication was allowed prior to the beginning of the round and the group was informed at the start of the round that at the conclusion of the time for that round, the contributions would be anonymously shown to the group.
Risk	Binary variable that indicates whether there was a risk of public and private goods being lost in that round.
Size of Individual Public Good Loss (t-1)	The number of public good tokens a player lost when the white marble was drawn in the risk game.
Size of Individual Private Good Loss (t-1)	The number of private good tokens a player lost when the white marble was drawn in the risk game.
Rounds since Public Good loss	The number of rounds that have passed since the group suffered a covariate shock and lost 50% of their public goods.
Trust	A 5 point ordinal variable answering the question "How much do you agree with the following statement? *I trust everyone*" – Strongly Agree to Strongly Agree
Willingness to take risks	A 7 point ordinal variable answering the question "When thinking about investing and borrowing are you a person who is fully prepared to take risk or do you try and avoid taking risk?" – Do not take any risks to Fully prepared to take risks
Food Security	The Food Consumption Score for the household based on their consumption for the week prior to the experiment.
Livestock	The number of Livestock owned by the household
Log Income	Log of all agricultural and non-agricultural income
Gender	A binary variable to indicate the gender of participant
Education	Number of years of formal education – note that high school runs until Year 12 in Namibia.
Health	The number of days the participant was sick in the past 12 months
Shock Index	A shock index consisting of the seven types of shocks, and their impact (none = 0, low =1, medium = 2, high =3). The index is the sum of total impacts across the different shock types.
Comprehension	The sum of correct answers in the comprehension test which was administered after the instructions were given to participants. There were a total of 8 questions. It should be noted that all comprehension tests were corrected, and participants misunderstandings corrected prior to commencing the experiment.
Semi-remote Villages	Binary variable reflecting whether the participant resides in the semi-remote villages of Kalundu and Sifuha.
Remote Village	Binary variable reflecting whether the participant resides in the remote village of Malindi.

Appendix 2: Full regression tables

Table 22: Regressions without interaction terms

	Games 1 and 2		Game 2 (Risk)		Game 1 (No Risk)	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Dependent Variable	Contribution to the public good (Percentage of tokens contributed to Public Good)	Total Effort (Number of Tokens found per round)	Contribution to the public good (Percentage of tokens contributed to Public Good)	Total Effort (Number of Tokens found per round)	Contribution to the public good (Percentage of tokens contributed to Public Good)	Total Effort (Number of Tokens found per round)
Rounds	1-20	1-20	11-20	11-20	1-10	1-10
Within or between-individual variation?	Within & Between individual		Between-individual		Between-individual	
Regression	GLS, RE	Poisson, RE	GLS, RE	Poisson, RE	GLS, RE	Poisson, RE
			Treatments			
Communication (Game 1)	0.040	0.064***			0.065	0.072***
	(-0.037)	(-0.021)			(-0.04)	(-0.015)
Observation (Game 1)	-0.017	0.084**			-0.002	0.086**
	(-0.034)	(-0.037)			(-0.039)	(-0.039)
Observation & Communication (Game 1)	0.174***	0.057**			0.216***	0.054
	(-0.06)	(-0.027)			(-0.06)	(-0.029)*
Communication (Game 2)	-0.019	0.088**	-0.026	0.092**		
	(-0.038)	(-0.036)	(-0.036)	(-0.039)		
Observation (Game 2)	0.043	0.007	0.040	0.004		
	(-0.036)	(-0.019)	(-0.032)	(-0.029)		
Observation & Communication (Game 2)	0.059	-0.045***	0.034	-0.018		
	(-0.04)	(-0.015)	(-0.024)	(-0.015)		
Risk	-0.073*	0.125***	-0.245**	-0.134***		
	(-0.041)	(-0.018)	(-0.102)	(-0.048)		
			Game factors			
Size of Individual Public Good Loss $_{(t-1)}$	0.002	-0.001	0.000	0.000		
(Covariate game shock)	(-0.003)	(-0.002)	(-0.003)	(-0.002)		
Size of Individual Private Good Loss $_{(t-1)}$	-0.011	0.004	-0.002	0.006		
(Idiosyncratic game shock)	(-0.007)	(-0.009)	(-0.007)	(-0.01)		
Rounds since Public Good Loss	0.000	0.000	-0.001	-0.003		
	(0.000)	(0.000)	(-0.004)	(-0.005)		
			Behavioural Characteristics			
Trust	0.007	-0.015	0.018	-0.007	-0.001	-0.017
	(-0.012)	(-0.012)	(-0.013)	(-0.014)	(-0.014)	(-0.012)
Willingness to take risks	-0.001	0.008	0.001	0.003	-0.004	0.012*
	(-0.008)	(-0.007)	(-0.008)	(-0.007)	(-0.008)	(-0.007)
			Income and wealth			
Food Security	0.000	0.000	-0.001	0.000	0.000	0.000
	(-0.001)	(-0.001)	(-0.001)	(-0.001)	(-0.001)	(-0.001)
Livestock	0.000	0.001**	-0.001	0.001***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Income	0.001	-0.008*	-0.008	-0.008	0.010	-0.011**
	(-0.009)	(-0.004)	(-0.01)	(-0.005)	(-0.01)	(-0.005)
			Respondent Characteristics			
Gender (Male = 1)	0.032	-0.211***	0.019	-0.218***	0.043	-0.198***
	(-0.038)	(-0.036)	(-0.046)	(-0.037)	(-0.039)	(-0.038)
Age	0.001	-0.011***	0.001	-0.011***	0.000	-0.010***
	(-0.001)	(-0.002)	(-0.002)	(-0.002)	(-0.001)	(-0.002)
Education	-0.012**	0.001	-0.009	0.002	-0.015***	0.000
	(-0.006)	(-0.006)	(-0.009)	(-0.007)	(-0.005)	(-0.006)
Health (Days Sick)	-0.001	-0.001	0.000	0.000	-0.001	-0.002
	(0.000)	(-0.002)	(-0.001)	(-0.002)	(-0.001)	(-0.001)
Shock Impact	-0.004	0.007***	-0.003	0.008***	-0.005	0.005*
	(-0.003)	(-0.002)	(-0.004)	(-0.003)	(-0.003)	(-0.003)
Comprehension	-0.019*	0.017*	-0.013	0.019*	-0.023**	0.014
	(-0.01)	(-0.009)	(-0.012)	(-0.01)	(-0.01)	(-0.009)
Semi-Remote Village	0.079	-0.103**	0.164*	-0.090**	0.005	-0.070
	(-0.071)	(-0.044)	(-0.088)	(-0.043)	(-0.071)	(-0.048)
Remote Village	0.296***	0.220***	0.124***	0.021	0.349***	0.222***
	(-0.081)	(-0.046)	(-0.025)	(-0.027)	(-0.076)	(-0.042)
Constant	0.657***	2.020***	0.757***	2.233***	0.693***	2.047***
	(-0.154)	(-0.144)	(-0.164)	(-0.148)	(-0.146)	(-0.142)
Log(sigma)		-4.19		-4.59		-4.72
Sigma		0.12		0.10		0.09
N	4074	4074	1935	1935	1935	1935
Number of Groups	215	215.00	215	215.00	215	215.00
Log likelihood		-8614		-4138		-4023
R-squared - within	0.05		0.01		0.05	
R-squared – between	0.45		0.38		0.57	
R-squared – overall	0.21		0.22		0.32	
sigma_u	0.14		0.17		0.15	
sigma_e	0.25		0.22		0.24	
Rho	0.25		0.37		0.29	

Note: * = 10% significance level, ** = 5% significance level, *** = 1% significance level. Source: Sikunga Survey Data 2014; own analysis.

Appendix 3: Experiment Procedure

1. Gather the group at a central location in the village

   As we were conducting a lab-in-the-field type experiment we selected a central location within the village where the randomly selected participants would meet at one of the three allocated times (morning, midday, afternoon). Non-participants were kept away from the area so as to limit the impact of individual's decisions from third-party observers.

2. Complete pre-game Survey

   Immediately after the five participants were gathered in the single location, they were given the pre-game survey. The pre-game survey consisted of two components; general capability self-assessment and the risks and behavior components. We conducted a willingness to take risks, and risky behavior survey prior to completing the experiment, as we did not want to prime participants with a lottery exercise prior to the experiment, nor did we want losses or gains from the public goods game to influence lottery choices following the experiment. Questions for the willingness to take risks were based on a scale from 1-7 and included general and financial risks. Risky behavior questions focused on the likelihood of undertaking risky actions such as smoking, gambling, and unprotected sex.

3. Give Instructions

   Following the pre-game survey, the experimental set-up was explained in detail to the group (please see online resources for the experiment instructions). To ensure that all participants had understood the instructions we implemented a comprehension test. Answers were immediately corrected, and individuals were given the correct answers. We also use the number of correct answers in the comprehension test as a control variable and find that it did not influence levels of cooperation. The risk and communication treatments were not introduced at this stage.

4. Commence test round

   To ensure that all individuals understood how the real-effort task would be conducted, we introduced three test rounds, which would not be included in the random pay-out. The focus here was ensuring all participants followed the rules regarding the real—effort task (e.g. turning one token at a time, and only using one hand. Results did not change if the test-rounds were included or excluded from the analysis.

5. Commence public good games

5.1. Complete rounds 1-5 of the public good game, without risk

5.2. Introduce the communication treatment where relevant

5.3. Complete rounds 6-10 of the public good game, without risk

5.4. Introduce the risk aspect for the second public good game; provide refreshments

5.5. Complete rounds 1-5 of the public good game with risk (except for the baseline group, who played two games without risk)

5.6. Introduce the communication treatment where relevant

5.7. Complete rounds 6-10 of the public good game with risk (except for the baseline group, who played two games without risk)

5.8. Select which round from Game 1 and which round from Game 2 would be randomly paid out using the deck of cards.

6. Complete post-game Survey and pay participants their winnings

A detailed household survey was completed post game, where participants provided information on their socio-demographics, food security, risks and shocks in real life and other aspects including their familiarity with group members and their perceived locus of control.

Experiment Instructions

Instructions

Action: WELCOME

Welcome and thank you for coming today to participate in this research. Please listen to the instructions carefully, as it is important that you understand the game.

Action: PRE-GAME SURVEY

If you understand the instructions, and play the game, you can finish the game with a considerable amount of money, which will be paid to you in cash at the end.

We will explain how your payment is determined later on in the instructions.

Unless directed by the Terry we ask that you do not speak to any of the other participants during the session. If, at any time, you have a question, please raise your hand, and Terry will answer your question. When directed you will be asked to turn your chairs around so that your backs are facing each other. Once we have asked you to turn your chairs around, please do not try to turn around and look at other participants or what they are doing.

If you speak to other participants during the game, without being given the opportunity by the experiment leader, we will stop the game, and all your winnings will be forfeited.

The experiment will last between 90 minutes to 2 hours.

Firstly to explain the setup. When participating in the experiment, you will all sit with your backs facing the middle of the circle. You will also notice that we have placed ‘walls’ separating each of you. This is so that all your actions will be kept secret from other participants, and they won’t be able to see your decisions and actions. We will also play some music in the background, so that again, the other participants will not be able to hear what you are doing. You should all have in front of you the following:

1. 1 Green Bucket
2. 1 Yellow Bucket
3. 1 Pile of green plates
4. 1 Pile of yellow plates
5. 1 folder with pen and a survey
6. And two plastic chips
7. Attached to each chair, you will find a Player Number for yourself, and all the other participants.

The game we play will make use of the plates in front of you. As you can see, there are several plates stacked on top of each other. Each plate has several white markers or “chips” on them.

Instructions Public good game: Game 1

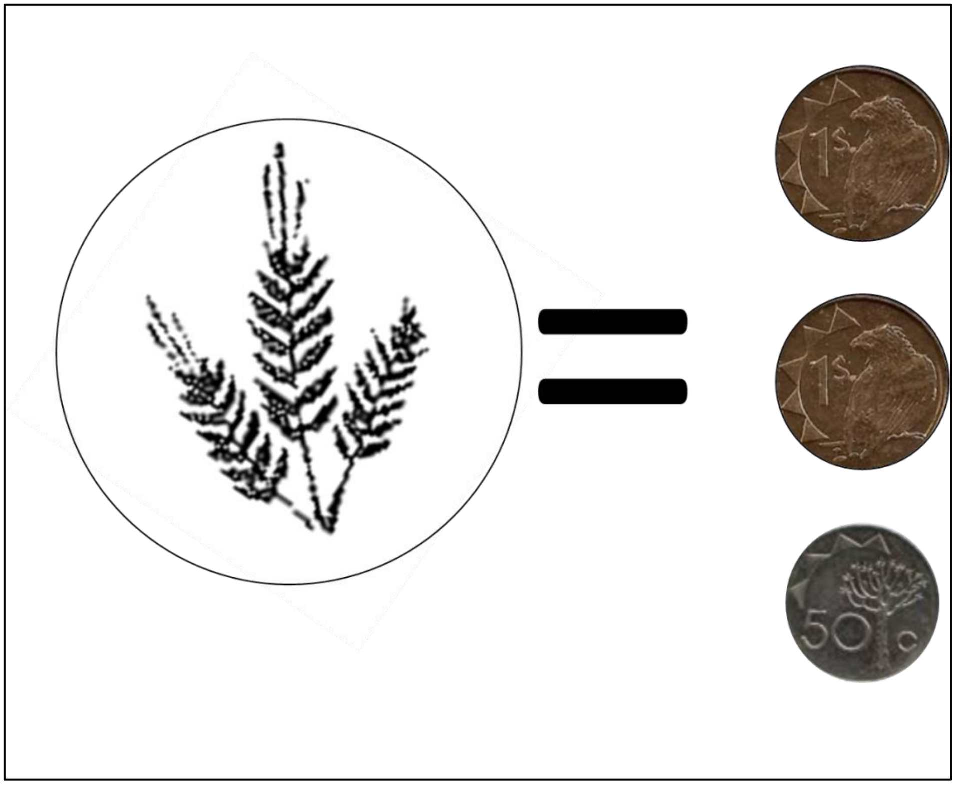
There are two different colors. The green colored plates contain many white plastic chips. One of the plastic chips on each green plate is marked with a Tree, the rest are blank. To show you what is on the marked chip, we have placed one on your table in front of you. Please hold up the chip marked with a tree.

The other yellow plates also contain many white plastic chips. In each yellow plate, there is one chip marked with Wheat, the rest are blank. Please hold up the chip marked with Wheat.

During the game, you will be given the opportunity to search through either the Green Plates, or the yellow Plates, to find the chips that are marked. When you find a wheat chip, please take it from the yellow plate, and put it in the yellow bucket. When you find a Tree Chip, please take it from the Green Plate and place it in the Green Bucket.

For each chip marked with Wheat, you, as an individual, will be given \$2.50. That is, every chip with Wheat on it is worth \$2.50. We have hung a poster to make this clear, if at any time you are confused – please look at the poster. The Wheat chip represents an activity where you work alone for yourself. Like working on your corn or wheat fields, or managing your livestock.

Figure 7: Value of Wheat Chips



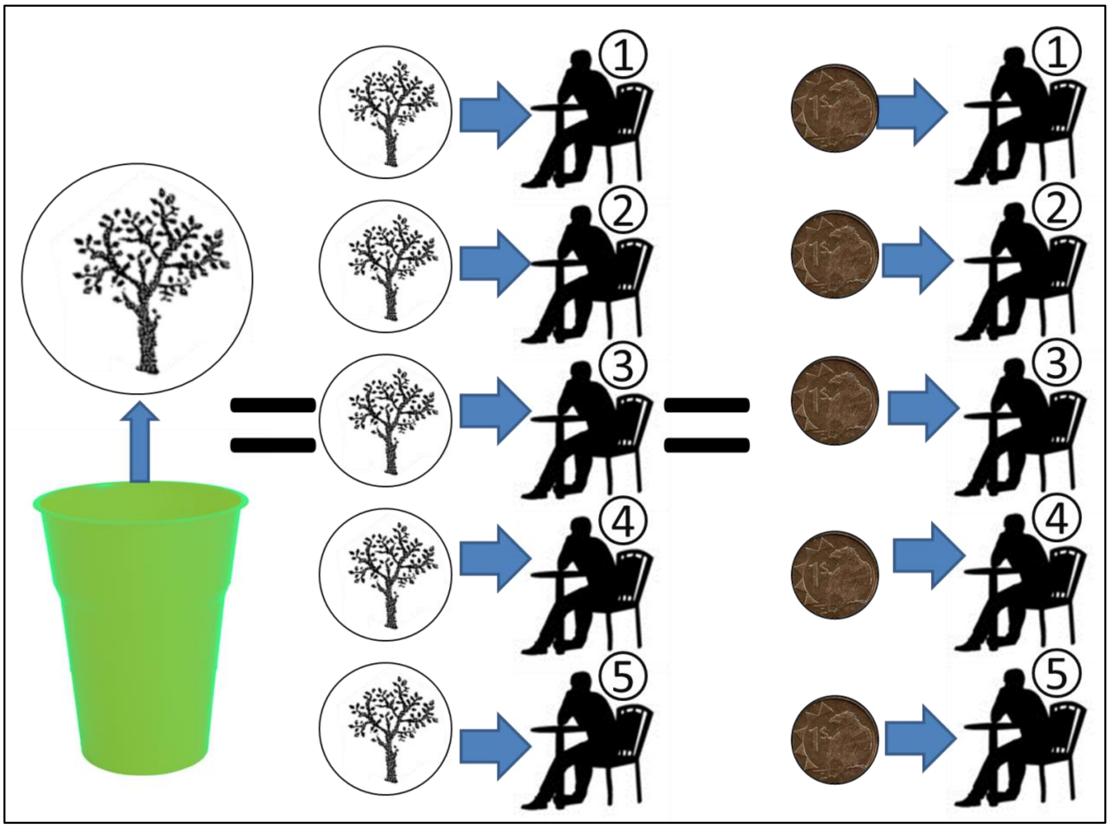
Source: Own design

The Tree chips represent an activity where you work together with others to do something good for the Sikunga Conservancy. For example, planting trees to regenerate forest, cleaning up rubbish to make the area more attractive to tourists. Such activities benefit not only yourself, but also other households in Sikunga. Therefore,

For every chip marked with a tree that you find we will give each other player in the game a Tree chip. So, if Player 1 finds one Tree Chip, we will give all other players one tree chip. If Player 1 and Player 2 finds one Tree Chip we will give all other players 1 tree chip from Player 1 and one tree chip from Player 2.

Each individual Tree Chip you hold at the end of each round is worth N$1. However, the value of each Tree Chip you find, is worth $5 for the whole group. To explain the way the Tree Chips earn you money, we have again prepared a poster. Here you can see, a player finding a Tree Chip from the green plate. Then you can see that each player will then receive 1 Tree Chip - so finding 1 Chip means the group receives 5 chips in total – 1 for each player. Then, you can see that after we have handed out the extra tree chips to each player, that each Tree Chip is worth $1. So, in comparing the value of a Wheat Chip, looking at the other poster – we see that a single Wheat chip is worth $2.50 and a Single Tree Chip only $1. However, if you look at the total, you see that by finding one Tree Chip, the group can earn $5 – which is twice as much as $2.50.

Figure 8: Value of Tree Chips



Source: Own design

You will have 2 minutes to find as many Wheat or Tree chips as you choose. There are no limits to how many chips you can find within the 2 minutes and thus how much money you earn. It is your decision as to which chips you search for, and for how long. You may switch between what chips you search for at any time during each round. A Wheat chip is worth $2.50 when you find it. A tree chip is worth $5 to the group when you find it, but shared across the group, each player will earn just $1.

To make sure you understand the game, we will work through some examples. These examples have been prepared with 5 imaginary players. In the first example, each player searches only for wheat. Here we can see their earnings.

Action: Work through examples – referring to handout that players have

Example 1

Player	Number of Wheat Chips found	Value of Wheat Chips	Number of Tree Chips Found	Number of Tree Chips received from others	Value Earned from Others finding Trees	Total Value Earned
1	1	$2.50	0	0	0	$2.50
2	1	$2.50	0	0	0	$2.50
3	1	$2.50	0	0	0	$2.50
4	1	$2.50	0	0	0	$2.50
5	1	$2.50	0	0	0	$2.50

Example 2

Player	Number of Wheat Chips found	Value of Wheat Chips	Number of Tree Chips Found	Number of Tree Chips received from others	Value Earned from Others finding Trees	Total Value Earned
1	0	0	1	4	$1+$4	$5
2	0	0	1	4	$1+$4	$5
3	0	0	1	4	$1+$4	$5
4	0	0	1	4	$1+$4	$5
5	0	0	1	4	$1+$4	$5

Example 3

Player	Number of Wheat Chips found	Value of Wheat Chips	Number of Tree Chips Found	Number of Tree Chips received from others	Value Earned from Others finding Trees	Total Value Earned
1	1	$2.50	0	4	$4	$6.50
2	0	0	1	3	$1+$3	$4
3	0	0	1	3	$1+$3	$4
4	0	0	1	3	$1+$3	$4
5	0	0	1	3	$1+$3	$4

Example 4

Player	Number of Wheat Chips found	Value of Wheat Chips	Number of Tree Chips Found	Number of Tree Chips received from others	Value Earned from Others finding Trees	Total Value Earned
1	1	$2.50	0	1	$1	$3.50
2	1	$2.50	0	1	$1	$3.50
3	1	$2.50	0	1	$1	$3.50
4	1	$2.50	0	1	$1	$3.50
5	0	$0	1	0	$1+$0	$1

However, these examples are for just one round. There will be 10 rounds, and each round will proceed as follows. We will organize the plates and cups on your table. We will then count down from 3 to 1, for the start of the two minutes. We will then play the music. This music will inform you of the time, as well as keep your effort levels secret from others. At the end of the two minutes, you will all stop searching immediately. During this time, please remain quiet and do not talk to others. We will then walk round and collect the number of tree chips found, if any, from each individual. We will then write down on your sheet, how many tree chips you have received from the rest of the group. Once we have written down the number of tree chips you have received from the rest of the group, you can calculate how much money the tree chips earned (Column F player sheet) and then the Total Value earned in the round (Column G on the player sheet).

To make sure everyone understands the game, we will play a test run that will last three rounds. If you are unsure how the game works during the test run, please ask Terry questions. Remember, it is your decision alone, to search for Tree Chips or Wheat chips.

The actual game, where you can earn money, will consist of 10 rounds. Your payment at the end of the session will include one randomly selected round of this game. Before we can start, we need to introduce the player sheet briefly.

Figure 9: Example of the playing sheet for game 1

Game 1:

	A	B	C	D	E	F	G
	You - Wheat Chips You Found		You – Tree Chips You Found		Others - Tree Chips received from group		Total Value Earned
	Quantity	Value of each chip =N$2.50	Quantity	Value of each chip =N$1	Quantity	Value of each chip =N$1	= B + D + F
Game 1							
Round 1							
Round 2							
Round 3							
Round 4							
Round 5							
Round 6							
Round 7							
Round 8							
Round 9							
Round 10							
	A	B	C	D	E	F	G

Source: Own design

As you can see, the player sheet as White Columns and Grey Columns. The White Columns are to write down the number of Chips you found or are given. The Grey Columns are to write down the value of the chips you found. We have given you a calculator to help with these calculations. You will notice that on the sheet, each column has a Letter – A to G. Under the heading “Wheat Chips” in Column A, the White column, you write down how many Wheat Chips you found at the end of each round. In the grey column under Wheat Chips, in Column B, you write down the value of the Wheat Chips you found. Each Wheat chip is worth $2.50.

Just to be clear on the rules. There are no limits to how many chips you can find within the 2 minutes. There are however some rules to searching:

- You can only use one Hand – not two. The hand you are not using may hold the plate steady. Should you use two hands, you will be ineligible to receive winnings for the round.
- You may only use one search method. You must start in the top left hand corner, and work your way down the column. Once you reach the end, you may then start at the top of the next column, again working your way down to the bottom.
- Each chip you find, please place in the coloured buckets on the table in front of you.

Action: Complete “Control Questions” Survey

Action: Correct Survey and explain the mistakes, ensure they understand why their answer was wrong, and what the correct answer is

Action: Move Chairs and Start Test Run

Now you all have an understanding of the task for each of the 2 minute rounds. Please turn your page and you will see the playing sheet for Game 1. You will see that there are 10 rounds. At the end of our time together, we will randomly select one of these rounds as a group, and this will determine how much money you will win. Just a reminder on the rules:

- You can only use one Hand – not two. The hand you are not using may hold the plate steady. Should you use two hands, you will be ineligible to receive winnings for the round.
- You may only use one search method. You must start in the top left hand corner, and work your way down the column. Once you reach the end, you may then start at the top of the next column, again working your way down to the bottom.
- Each chip you find, please place in the coloured buckets on the table in front of you.

Action: Start Game 1

Action: After 5 Rounds, explain Communication Treatment where relevant

Action: Move Chairs into the middle and explain Game 2

Instructions Public good game: Game 2

Now we will play another game, you will be given 2 minutes to search through the plates to find the chips with Wheat or tree markers. But this time there will be a small change. Now there is a chance, a risk, that despite your effort to find chips, there may be some bad luck, and you might lose half the Wheat chips and or half your Tree chips.

What will happen, is at the end of two minutes, someone from the group will be asked to select a marble from this bag. We will start with player 1, and each round will move sequentially around the group, so that each person will select a marble for the group twice in the game. This bag contains 7 black marbles and 3 white marbles. If a black marble is selected, the trees will be collected, multiplied, and then shared amongst the group such as in the first game. However, if a white marble is selected, the trees will be collected, multiplied, and then half the trees will be taken away. The remaining trees will be shared amongst the group. The trees that are removed, lost, you and the group will not receive any money for them. The remaining trees can then be multiplied by the value on your sheet to calculate your potential winnings for the round.

Then, each person will individually select one marble from the bag containing 7 black marbles and 3 white ones. If a black marble is selected, then you will multiply the number of the chips by the values on the playing sheet.. However, if a white marble is selected, half your Wheat Chips will be removed, and you will not get the chance to be paid for them. You can then multiply the remaining number of chips, by the value on the page to calculate your potential winnings for the round. This process will be completed after each round, that is, after every 2 minutes.

Your payment at the end of the session will include one randomly selected round of this game. You will however also notice that the value of the chips has changed. The value of 1 Wheat Chip is now N$3.00 and the value of one tree token is N$1.20 for an individual, or N$6.00 for the group.

Action: Move Chairs and Start Game 2

Action: After 5 Rounds, explain Communication Treatment where relevant

Action: End Game 2

Action: Commence Post-game Survey

Additional Instructions for Treatments – implemented after 5 rounds

Cheap Talk

You were told earlier that you were not allowed to talk to each other. From now until the end of the game, you will, as a group, at the start of each round, be given the opportunity to discuss how much effort to invest searching for Tree chips. However, how many Wheat chips or tree chips you search for will not be known by the group, and you can still decide by yourself how much time to spend searching for which chips.

Observation

As sometimes happens, we observe our neighbours doing things, such as working in the field, or catching fish, or collecting rubbish to make the village cleaner. From now on, until the end of the game, as a group, you will be able to see what contributions the total number of tree chips consisted of. For example if there were 8 tree chips found by the group, that the contributions consisted of 1,0,4,2,1. However, you will not know who gave 1,0,4,2, or 1. That is, the contributions will not be assigned to any player, and will be presented in a random order to the group. I want to stress that no-one will be able to tell how many trees you as an individual contributed to the group – this will remain secret.

5 Conclusion

As with any detailed analysis of a single study site, there may be contextual variables that are unique to the area which therefore places some limits on the transferability of results. The future research implications of the three essays are outlined below.

In the first essay, the analysis identified four unique livelihood strategies, and the role the income from natural resources plays in improving income equality within the conservancy. That income from natural resources is heavily skewed towards households rich in physical and financial assets indicates potential issues with elite capture. The conservancy management thus faces the challenge of how to better ensure that natural resources are not overexploited by households who already control much of the physical and financial wealth in the community, whilst ensuring the natural resource extraction rates remain sustainable. A possible approach would be to empower the asset-poor households, particularly those headed by females, to gain access to the necessary equipment, or overcome labour shortages, so that they are more able to benefit from the natural resources. This however would need to be counterbalanced by measures that simultaneously ensure the overall sustainability of natural capital.

The second essay highlights that the structural linkages between the natural resource and non-natural resource based sectors demonstrate that the structure of the village economy is unsustainable and unequal. The inherent inequality in the structure of the economy means that pro-poor development activities are difficult to drive in the current structure of the economy. Potential structural adjustments may be small, such as future investments in employment or infrastructure being prioritised for the isolated villages within the conservancy.

Our conclusions regarding the likely development path based on the economic structure are however based on the static analysis of constrained multipliers. The assumptions behind multiplier analysis of SAMs are however unrealistic (e.g. that prices are fixed and changes in demand are met by changes in production volumes, and sectoral linkages are linear), and thus computerised general equilibrium models (CGE), based on the structure of SAMs would be far more appropriate for policy analysis.

In the third essay, the issue of cooperation under risk, and more broadly the implications this has on community driven development is analysed, a theme that has generally been neglected (McCarter et al., 2010; Van Dijk et al., 2004). Finding that risk has a negative impact on cooperation levels raises potentially challenging questions for development policies, such as CBNRM, where success is dependent upon cooperation in areas where risk is omnipresent, and households regularly on the receiving end of idiosyncratic and covariate shocks. Practitioners may have to consider the need to mitigate risks within community development via innovative insurance mechanisms, whilst researchers need to broaden the understanding of why risk has a negative impact on cooperation.

However, one swallow does not make a spring, and the results from lab-in-the-field experiments must be viewed with caution in policy making (Harrison, 2014). The results from the experiment are however an eye-opener for future research. The impact of cooperation under risk needs to be more broadly explored at an individual level in traditional laboratories as well as in the field. However, this alone is insufficient, and randomised control trials to properly measure the impact of mitigated and unmitigated risks on cooperation would form a far more robust basis for policy interventions.

As outlined in the study area description, as the conservancy had a positive reputation for equality, transparency and good governance, the magnitude of positive impacts of CBNRM are estimated to be towards the upper bounds. The approach of Angelsen et al. (2014) thus forms a solid basis for future research, in that the studies need to be replicated in other regions and other CBNRM communities to isolate which factors drive the successful implementation of CBNRM programs, with sustainable resource use, equitable distribution of benefits and costs, and stable economic growth.